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An engineering valuation of the principle of self-propelled transport for farm machines

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AN ENGINEERING VALUATION OF THE PRINCIPLE OF
SELF-PROPELLED TRANSPORT FOR FARM MACHINES

by

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INTRODUCTION

Since the appearance of the steam or external combustion engine in agricultural work there has been a continuous effort to develop new machines that are capable of propelling themselves on their own power. The first developments were brought to view in machines that were semistationary in nature but could, on their own power, move from one operating station to the other. These machines were limited in their operating scope, because of the few conditions under which they could travel due to their clumsiness, excessive weight, low power output per unit of weight, high labor requirements, and low efficiency from fuels. However, the machines did furnish the basic ideas for more efficient developments.

With the development of the internal combustion engine, and fuels and lubricants for its use, whereby machines with greater power per unit of weight were possible, ones that could transport themselves and do a greater amount of work were constructed. From crude tractors, trucks, automobiles, and other machines they have been improved into the present-day streamlined powerful machines of industry, transportation, and agriculture. Usually machines employing the principle of self-propelled transport first appeared in industry where there was a concentration of high priced labor, a large volume of heavy work to be done, a large amount of operating capital, and where a reduction in unit cost could be accomplished by the use of this type of machine. This principle was brought into agricultural machinery first by ranchers of the Pacific Northwest and West, or by wealthy men of industry who farmed as a sideline operation and the machines were farmer built. There was, and is a continuous striving in agriculture to increase the net returns to a figure comparable to those from industrial work by giving the farmer greater mechanical advantage. With the decrease in available qualified labor, the increase in farm wages, and the intricate processes of modern farming, along with the higher prices for agricultural products, the demand for farm machines embodying this principle has been expressed in many forms.

Some of the machines involving the principle of self-propelled transport apply to small areas of specialized farming of high-priced crops and are the self-propelled nut, lima bean, and fruit harvesters. A few that apply to large farms of a one-crop nature are the self-propelled side-delivery rake, hay press, corn picker, cotton picker, beet harvester, and ensilage or hay chopper. The self-propelled machine that is most widely used has had one or more produced each of five times since 1887 and used successfully by wealthy farmers, is the self-propelled combine which has now been proven and is produced in sufficient quantity, and at such a price that even the farmer with a relatively small acreage can own or have access to its use.

Small grain, soybeans, or other seed crops are produced in every state of the United States, and since the combine is the most versatile, if not the most economical, machine for harvesting these crops, field research in this study will be confined to its use. The corn picker is the grain-harvesting machine of secondary importance throughout the United States due to the wide distribution of the corn crop, so the history of its development will be reviewed in this study.

The self-Propelled combine has gained rapidly in popularity among ranchers and farmers in the Great Plains and Pacific Northwest small-grain producing states, but to be accepted generally it must make an economic contribution to the farming enterprise in sections like the Corn Belt, where large quantities of small grain are produced as secondary crops. The farmer is interested in such features (1) as comfort of the operator, convenience and flexibility along with other features that the self-propelled combine offers, but these must add up to lower harvesting costs or else the machine will be limited in its use in these sections.

During periods like the present, when agricultural income is high and available farm labor is very scarce, the farmer can afford to invest more in high-priced machinery.

He can also be more interested in high performance features that a particular machine may possess. Under these conditions, along with the greater demand for custom harvesting, the self-propelled combine is being used in areas outside of the Grain Belt. However, like all high performance agricultural production machines of the past, its economic adaptability to such conditions is being questioned.

Primarily, in farming as in other business, the objective is to lower production costs, and secondly to provide an extra amount of surplus time for maintaining and improving the farm land and structures. By more efficient utilization of his cropland through the increase of small grain in rotations, the farmer will do a better job of conserving his soil and may be able to lower production costs through the use of the self-propelled combine.

In order to lower production costs and effectively plan future operations, the farmer must not only know the capabilities of his present machines but where he could gain by making changes. The object of this investigation is to bring together material that may aid him in determining whether he could justify the use of the self-propelled machines in his enterprise. This applies particularly to Central Iowa and similar sections where the small-grain and soybean fields are relatively small and usually fenced on all sides, bounded by corn or other tall crops in regular fields or planted in many cases to strips in rotations, which would cause heavy losses due to opening fields with a pull-type combine, commercial windrower or tractor mower.

Field studies have shown that there is a difference in the grain losses by the methods of harvesting employing the pull-type over the use of the self-propelled combine, due to the heavy opening losses in making the initial round with the pull-type machine, or the other machines that were mentioned in the preceding paragraph, and that there is a difference in maneuverability in favor of the self-propelled machine. The problem in this investigation was to determine the over-all harvesting losses incurred by each type of machine, the power requirements, the labor requirements, the operating costs, and evaluate by time-study the performance features, such as flexibility, portability, and simplicity of adjustment of each machine, in operation under the same field and harvesting conditions. When the effects of the above factors and features were evaluated and expressed in dollars per acre or cents per bushel cost we had a basis for comparison.

REVIEW OF LITERATURE

Historical

Development of the combine

The first (2) combined-harvester and thresher or combine was developed by Samuel Lane of Hallowell, Maine, in 1828, but was never reported as having been used. In 1834-35, Hiram Moore and J. Hascall of Kalamazoo, Michigan (3) developed another that operated on similar principles to the present-day combine and which was fairly successful. This combine was pulled by 12 horses in its first field test on a three-acre field of wheat, and according to Mr. Moore's figures, it cost 82 cents per acre to thresh in contrast to $3.12-1/2 per acre by reaping and threshing.

Briggs and Carpenter invented a combine at Ft. Covington, Kentucky, in 1836 and it was demonstrated in Up-state New York that year. The Holt Company and its subsidiaries of Stockton, California, manufactured 14,000 big combines during the period from 1886 to 1929.

The grain-producing section of the United States in the 1870's and 1880's (4) was the Pacific Northwest and the principal small grain crop was wheat. A wheat harvest on one farm that was of historical note was one on Dr. Hugh J.

Glenn's farm in Coluse County, near Sacramento, California. The farm produced 45,000 acres of wheat in 1876, and was harvested with 21 headers 30 feet wide, and threshed on a large "Monitor" separator which threshed 6,570 bushels per day. It was claimed that it took only 15 minutes from the field until the wheat was sacked. The threshing scene was put in an oil painting and was called "Dr. Glenn's Million Dollar Wheat Harvest", which indicated that even in the 1880's the harvesting problem was of some magnitude.

A Mr. Ridley of Australia developed a header and thresher in 1845 that was the forerunner of the Australian stripper and thresher. Several types of large horse-drawn combines were being manufactured in Stockton, California, about 1887. The use of the combine was restricted to the Pacific Coast States from 1880 until about 1929 (5); however, by that time it was well established in that area. During, and immediately after, World War I, the combine was introduced into the Great Plains area. The type used here was smaller, pulled by wheel tractors and with mounted engine to operate the combine mechanisms. It was then predicted that combine harvesting would be confined to dry areas where large-scale farming was practiced. In the early 1930's (6) the small power-take-off operated type, usually 6 feet or less cutting width, was developed to answer the demand for soybean and small-grain harvesting in the Corn Belt, Northeast, and Southeast, where the acreage of soybeans and small grain per farm was small.

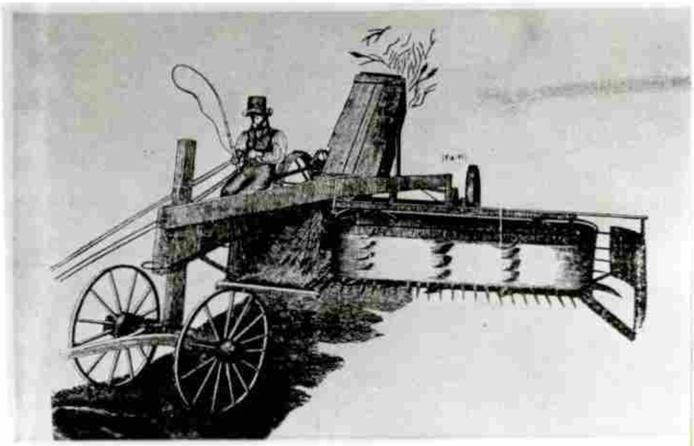


Fig. 1. The Briggs-Carpenter Combine of 1836

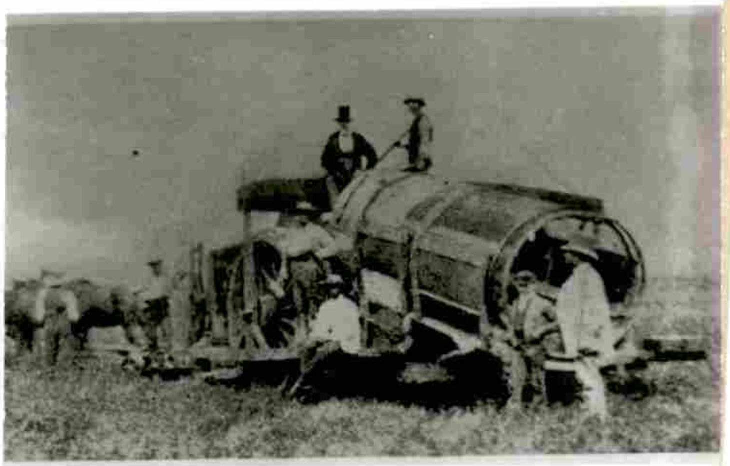
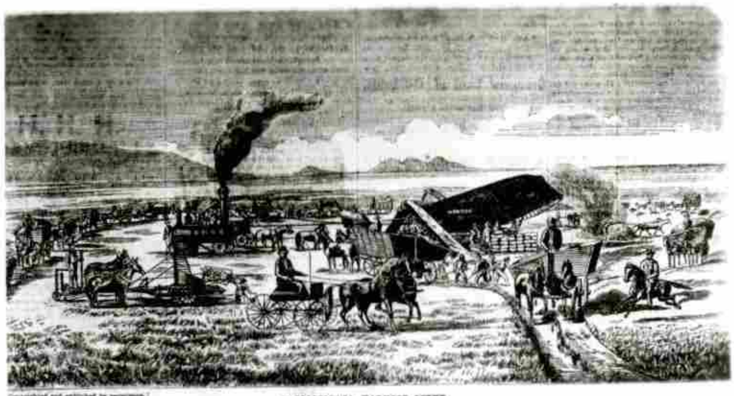


Fig. 2. The Hiram Moore Combine of 1850



Copyrighted and published by permission.] A CALIFORNIA HARVEST SCENE.

Fig. 3. Dr. Glenn's Harvest of 1876

Fig. 4. The Shippee Combine of 1884

Development of the self-propelled combine

Mr. George S. Berry (2) of Tulare County, California, who farmed about 4,000 acres of wheat, developed the first self-propelled combine in 1887. It was built around a 25-horsepower Mitchell-Fisher steam engine which furnished traction power. A 6-horsepower Westinghouse engine furnished power for the threshing mechanism and header knife. A single boiler furnished steam for both engines. The machine had a 22-foot cutting width, but the next year Mr. Berry modified it and made the cutting width 40 feet. This combine was reported as having done a successful job of harvesting, but due to its bulkiness and extremely high cost of production it was not reproduced. The Holt Company of Stockton, California (3) developed a self-propelled model about 1909 of which some machines were used until 1929. Other models were developed on a similar basis during the period from about 1915 to 1925 but were never put into extensive production because of their excessive cost and the low income from agricultural products. In 1928 (7) the Massey-Harris Company developed a model of the self-propelled combine but only 10 machines were produced due to the same reasons. In 1939 Massey-Harris came out with a model of the Clipper Self-Propelled Combine, and by 1944 the test machines had been tried thoroughly and were put into full production. At the present time five major farm machinery companies are manufacturing self-propelled combines, and probably others are yet to follow. Of the 104,888 combines produced in 1949 (8), 13,671 were self-propelled.

Development of the corn picker

Many corn-harvesting machines were developed during the period 1820 to 1892. Most of them were of the sled-type or patterned after the mower and reaper for harvesting the whole corn plant. Edmond W. Quincy of Illinois, or "Father Quincy" as he was known, obtained the first patent on a corn-harvesting machine in October 1850 (9). "Father Quincy" in 1850 also developed a machine with a revolving cylinder and four rows of metallic fingers that husked and shelled the grain. During the period 1880 to 1885 Patrick Lawler of West Lake, Iowa (19) built a model of the snapping roller-type corn picker and April 15, 1890 received a patent on this machine. The full-scale model, which had many of the features of present-day machines, worked, but due to lack of customers the picker was not put into production. These same principles were built into another picker by A. S. Peck of Geneva, Illinois, who received a patent January 5, 1892 (9). During the period 1850 to 1900 inventors had worked on machines that would remove the ears from the stalks; however, farm machinery manufacturers had pretty well given up the idea of pickers and produced corn binders until about 1902 when demands became so great from the farmers of the Corn Belt, who were interested in harvesting the corn as grain, that their interests were turned again to corn pickers. Following the basic principles that had been laid down by Lawler (9), Peck (9) and others, they made improvements on the machines and began to put them in the field.

The first machines were horse-drawn and got power for the mechanism from "bull-wheels" which gave them traction. These machines were of the 1-row and 2-row type. When tractors were developed with power-take-off drives the pickers were developed to get the power for operating the mechanism from the tractor rather than a bull-wheel. This development enabled pickers to operate much better under wet and frozen conditions. By 1928 a majority of the larger farms using corn pickers were using the 2-row type.

The present-day tractor-operated corn pickers are of the three principal types; the trailing, integral-mounted, and mounted-types. Of these types the mounted-type is gaining prominence due to its ability to enter a field at any point without the necessity of hand picking on opening strips, or causing excessive loss of corn due to broken down stalks.

Development of the self-propelled corn pickers and corn combines

After the development of the self-propelled combine and its successful operation during the war years, the Massey-Harris Company of Racine, Wisconsin (11) saw another great possibility for self-propelled machines in the corn harvest,

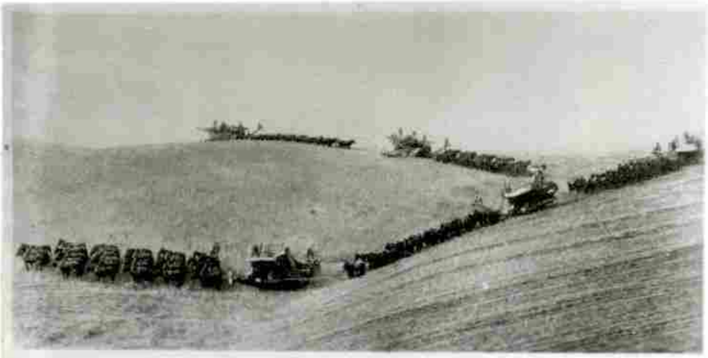


Fig. 5. Five Holt Combines near Walla Walla, Washington, 1890's

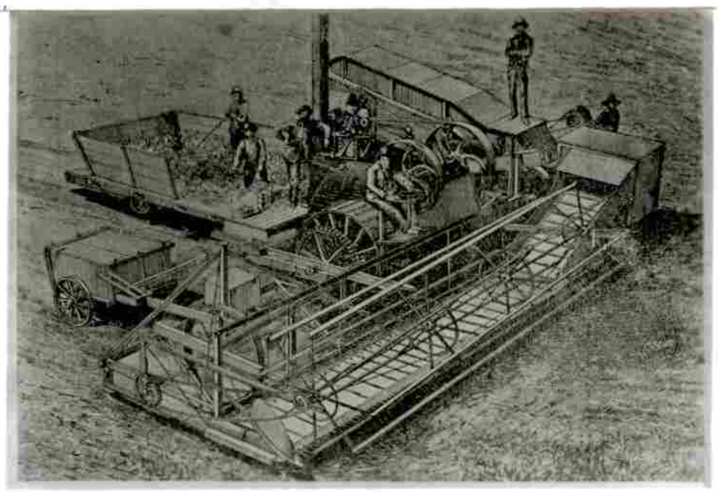


Fig. 6. Berry's Self-Propelled Combine 1887

Fig. 7. Holt Self-Propelled Combine about 1905

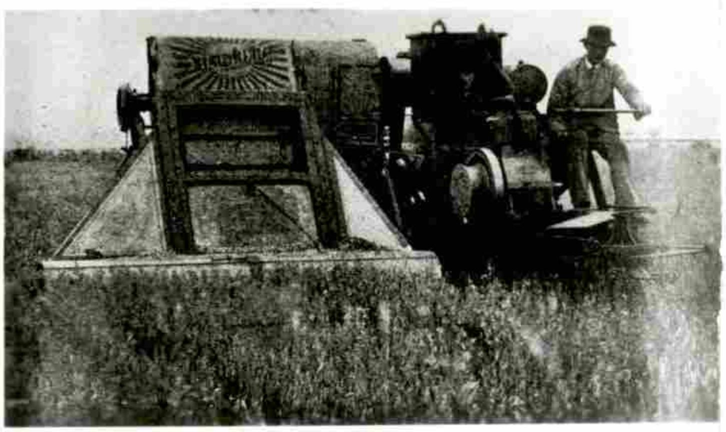


Fig. 8. Sunshine Harvester Company Ltd's "Sunshine Auto-Stripper" of 1926

and in 1946 produced a 2-row self-propelled corn picker. It employs the same general design and construction as the self-propelled combine and the operating principles of the other present-day corn pickers.

A 4-row corn combine was developed by John Eyestone of Upper Sandusky, Ohio, employing standard parts and assemblies mounted on surplus Army "Duck" chassis (12). This machine picks, husks, and shells corn in one operation and will harvest corn with as much as 40 per cent moisture.

Development of the Uni-Harvestor

The Minneapolis-Moline Implement Company (13) developed the first of a predicted ideal basic power unit, embodying the principle of self-propelled transport, called the Uni-Tractor. In January 1951 they began producing two quick detachable units, combine and corn picker, to mount on the power unit. Other units are to follow in the form of Combination Picker-Sheller, Wire Tying Baler, and Forage Harvestor. These units are mounted by one bolt, two slip pins, and two spring release pins. This unit has been tested for almost five years and is called the Uni-Harvestor, Uni-Combine, and Uni-Huskor. It is powered by a 4-cylinder M-M engine that develops 38 horsepower. Ground speeds may be varied from .96 to 2.2 mph in low, 1.9 to 4.5 mph in second, 4.3 to 9.78 mph in high, and .66 to 1.9 mph in reverse gears. It has a 9-foot header that can be adjusted to handle all grain and

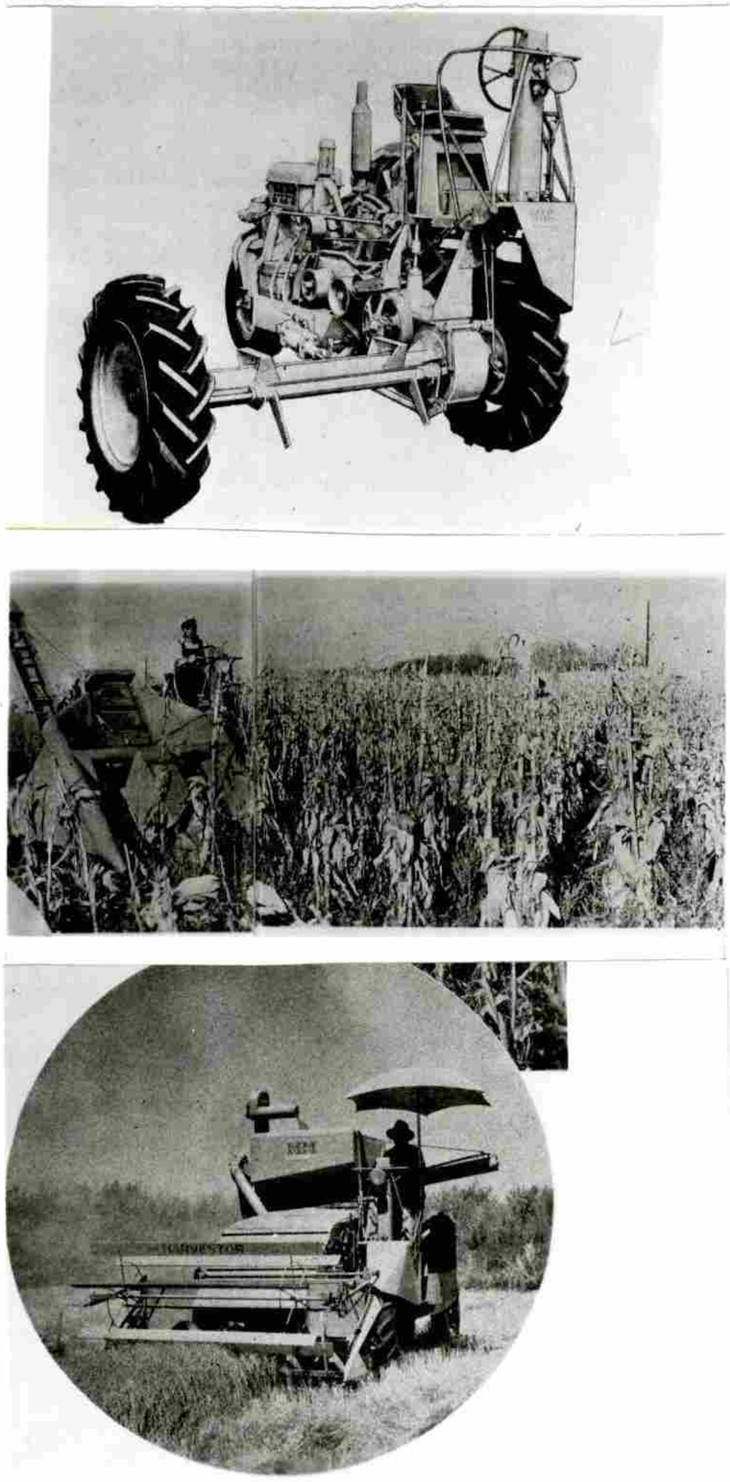


Fig. 9. Minneapolis-Moline's Uni-Harvestor, 1950

grass seed crops. It has Auto-Hydramatic control to regulate the height of cut from 2 to 24 inches. The Uni-Huskor attachment, which is similar to the 2-row corn picker made by the company, has four snapping rolls 53-1/2 inches long and eight 36-inch husking rolls, four rubber and four steel. The snouts are adjustable to five floating positions.

Development of other self-propelled farm machines

Many other farm machines have been, and are being, developed employing the self-propelled idea. A majority of these machines are developed in well-equipped shops on large ranches in specialized farming areas, or on one-crop type farms where they can be used profitably, due to a great labor shortage or an excessive wage rate. Others are being developed by wealthy men of industry who farm as a sideline, and the economy of production may not necessarily be a controlling factor.

Following are photographs and brief descriptions of a few of these machines involving the self-propelled idea used on specialized crops or under the conditions mentioned:

Mr. Harlan (14), of Dumar and Harlan, tomato, alfalfa, and beet farmers, near Woodland, California, produced a self-propelled side-delivery hay rake, using a Case rake, and building a frame with a rear-mounted engine.

Stephen Griset (15) and Sons, Raymond and Francis, of

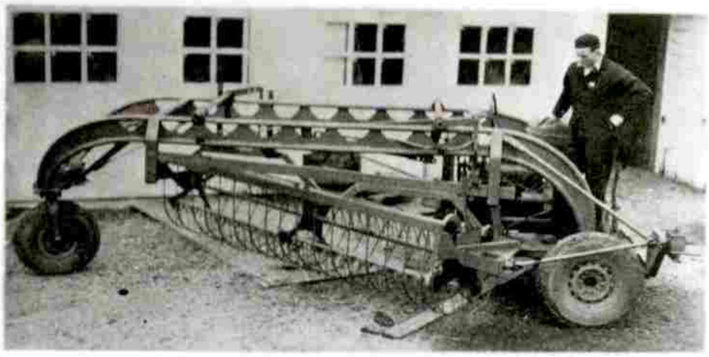


Fig. 10. Harlan's Self-Propelled Side-Delivery Rake, 1947

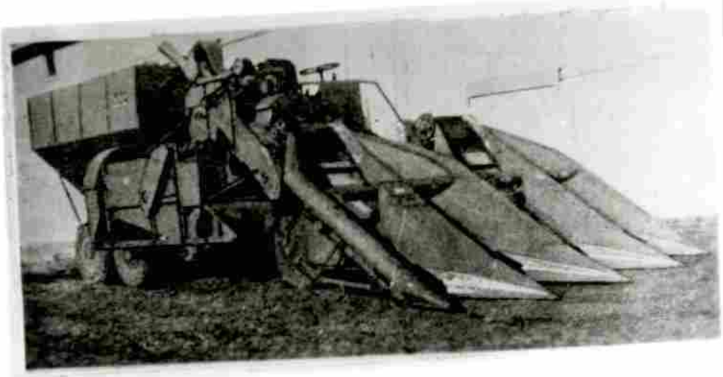


Fig. 11. Eyestone's Self-Propelled 4-Row Corn Combine, 1948

Santa Anna, California, and other green lima bean farmers built a self-propelled green lima bean harvester which harvests and shells lima beans from the windrow. The machine harvested 600 acres of beans the first season.

The English manufacturers "The Victory Machine Company Ltd." (16) of Newberry, Berkshire (England), developed the self-propelled potato harvester in 1947-48. It is a one-man operated machine which harvests and sacks 3 to 4 acres per day.

Charles Brown (17) of Minooka, Illinois, developed a 4-row self-propelled wireless checkrow corn planter, which is propelled by a 9-horsepower single-cylinder air-cooled engine.

Harold Folkerts (18) of Bristow, Iowa, constructed a self-propelled grain windrower with a 9-foot cutterbar that delivered the windrow to the center of cut by means of two canvasses operating in opposite directions. It is propelled by a 9-horsepower air-cooled single-cylinder engine.

Rousseau Establishments (19) of Orleans, France, developed a self-propelled "pickup" hay baler. It is a one-man operated machine and is composed of three distinct sections: baler, "picker", and power units. It is operated by a 44-horsepower water-cooled 4-cylinder engine that operates at 2000 rpm. It has three forward speeds and one reverse of 1.4, 2.5, and 4.1 miles per hour forward and 1 mile per hour

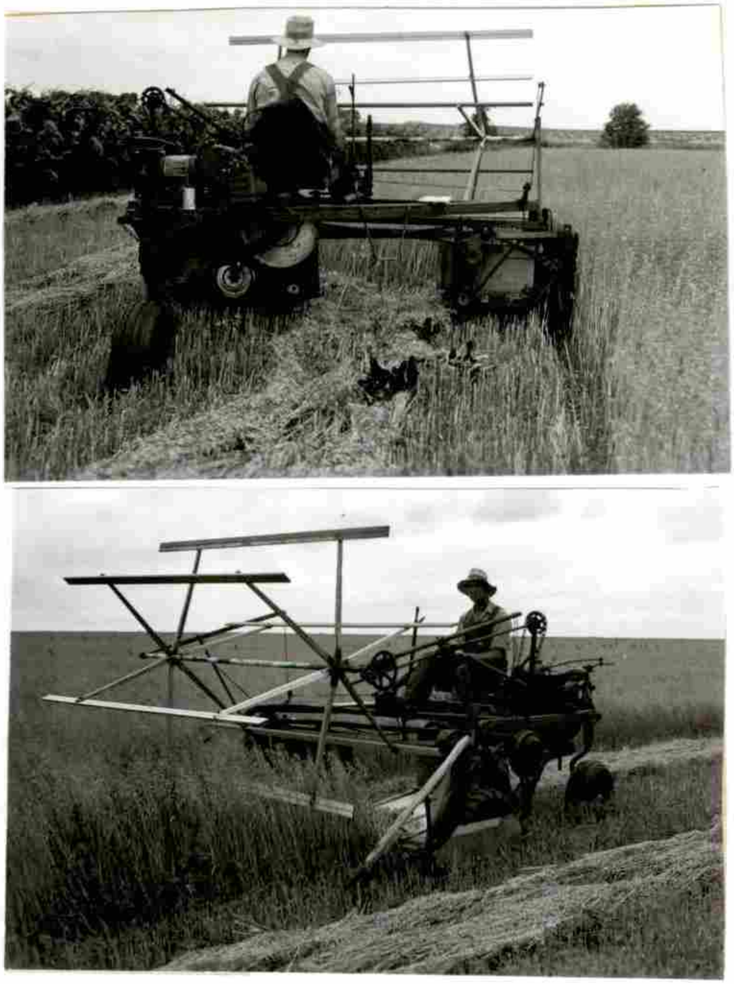


Fig. 12. Folkert's Self-Propelled Windrower, 1946

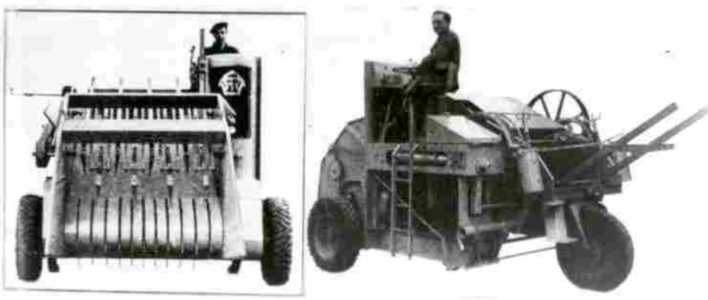


Fig. 13. Rousseau's Self-Propelled "Pickup" Baler (France), 1946

reverse. It produces a bale 3-1/2 feet long weighing from 16 to 32 pounds, and has a capacity of 3 acres or 5 to 7 tons per hour.

John Eyestone (12) of upper Sandusky, Ohio, constructed a 4-row self-propelled corn combine in 1947. He used standard parts and units mounted on a war surplus Army "Duck" chassis. The machine is powered by a 160-horsepower engine at 3600 rpm but has been operated at 1800 rpm and produced about 75 horsepower. It has 9 forward speeds of 1.3 to 20 miles per hour and operates on 1 gallon of gasoline per acre.

The Sunshine Harvester Company Ltd. (20) of Sunshine, Australia, developed the first self-propelled combine to be factory produced in 1926. It was a stripper-type harvester known as the "Sunshine Auto-Stripper". Only a few of these machines were produced. They did work successfully but due to the high cost they soon had no sale. It had a 12-foot cut, was powered by a 36-horsepower engine, had a 3-1/2 mile per hour top speed, and a capacity of 45 acres per day on one-half gallon of fuel per acre.

The Hiel Manufacturing Company of Milwaukee, manufacturers of hay dehydrators, developed a self-propelled hay chopper which has an 8-foot cutting width and powered by an engine of approximately 130 horsepower capacity.

Use and Performance

Brodell, Birkhead, and Peters (2) in their series of

Fig. 14. Hiel's Self-Propelled Hay Chopper, 1948

articles "Harvesting Small Grains and Utilization of the Straw", made a study of the acres of small grain produced, specific methods of harvesting, and the utilization of the straw by farming regions and by states in the United States.

United States Department of Commerce (22) lists oats-acreage, production and value by states from 1938 to 1949. United States Department of Commerce (23) lists corn-acreage, production and value by states from 1938 to 1949.

The Farm Implement News (24) in its special article "How Big Can an Oyster Grow?" made a tabulation of the production of farm machines during the period 1929 through 1947 by specific kind, and also the number of combines on farms by states in the United States in 1945.

The Farm Implement News (25) in its article, "Farm Equipment by Classes", made additional tabulations of the production of farm machines during 1948 and 1949.

The Farm Implement News (8) in its article "Machinery on Farms 1950", listed combines and corn pickers on the farms in the United States by states.

Hurst (26) in "The Field for the Small Combined Harvester-Thresher", explained the requirements and adaptability of the small pull-type combine.

Carroll (1) gave the design features and the performance characteristics of the self-propelled combine in his article

"Basic Requirements in the Design and Development of the Self-Propelled Combine".

Barger (18) in "Engineering-Management Aspects of Self-propelled Farm Machines", made a report on the comparative costs of harvesting with the pull-type and self-propelled combines.

Reynoldson, Kifer, Martin, and Humphries (5) in United States Department of Agriculture Technical Bulletin No. 70, "The Combined Harvester-Thresher in The Great Plains", made a study of the capacities, adjustments, and limitations of the various harvesting machines; and harvesting losses from the use of binders, threshers, and combines in the Great Plains area in 1928.

Hurst and Humphries (27) in "Performance Studies of Small Combines", made investigations of the performance characteristics and operating qualities of the small pull-type combine.

McCuen and Silver (28) for their article "Results of Field Tests on Small Combines", developed a large-sample method of field testing the small pull-type combine for harvesting losses.

Richey (29) in "Determining Combine Loss on the Farm" developed a simple method of checking combine losses that would permit the farmer to check the performance of his combine in the field.

The National Institute of Agricultural Engineering

(England) (3) explained a simple method and a large-sample method of field testing combines for losses in "Combine Losses with the Combine Harvester".

Gray, Hurst, and Humphries (31) in "Harvesting with Combines", explained the use and adjustment of combines for harvesting a group of the grain and seed crops of the United States.

Johnson and Barger (32) of Iowa State College, Agricultural Engineering Department, made an automobile survey to Allentown and also to Fort Dodge, Iowa, July 22, and July 25, 1948, respectively, of 156 fields comprising 3,705 acres of oats to determine the percentage of oats harvested in Central Iowa by various methods. The tabulations of this material are found in Tables 4 and 5 in "Presentation of Data".

Silver and Sitterly (33) in Ohio Agricultural Experiment Station Bulletin No. 491, "The Combined Harvester-Thresher in Ohio", October, 1931, made a study of the combining hours per day, acres of crops harvested per day, and per hour by various sizes of combines, cost per acre, labor requirements, and harvesting losses by each group of combine sizes.

McCuen and Silver (34) in Ohio Agricultural Experiment Station Bulletin No. 643, "Combine-Harvester Investigations in Ohio", July, 1943, made a study of combine harvesting losses, costs, capacities, and adaptability to Ohio conditions in this series of tests.

Bottum and Mayer (35) in Purdue Agricultural Experiment Station Bulletin No. 349, "The Adaptability of the Combine to Indiana Farms", made an interesting study of combine harvesting losses, costs, capacities and adaptability to Indiana conditions.

Jones (36) in Missouri Agricultural Experiment Station Bulletin No. 286, "The Combine Harvester in Missouri", May, 1930, noted a study of the losses, costs, labor requirements and capacities of combines in harvesting grain in Missouri.

Barger and Fenton (37) in Kansas State College Engineering Experiment Station Bulletin No. 45, April 15, 1945, "The Cost of Using Farm Machinery", set up procedures and methods of determining the cost of farm machinery applied to a unit of production.

Davidson (38) in Iowa Agricultural Experiment Station BP No. 37:282-99, "Life, Service, and the Cost of Service of Farm Machines on 400 Iowa Farms", made a determination of the costs per unit of production from farm machines in Iowa.

Barger and Heady (39) in <u>Iowa Farm Science</u> Vol. 2 No. 12, pages 1, 11, and 12, June, 1948, "Custom Rates for Farm Machinery", set up rates for custom work with power machines for Central Iowa conditions.

Downing (40) of the University of Saskatchewan made a study of the horsepower requirements of the conventional and high-speed type power-take-off operated pull-type combines for both draft and threshing mechanisms.

Zinthero (9) in United States Department of Agriculture Office of Experiment Station Bulletin No. 173, "Corn Harvesting Machinery", gave the history of corn as a crop and the history of corn harvesting machinery up to that date, including comparative costs, labor, and power requirements for harvesting by different methods.

Hobson and Wileman (41) in Purdue Agricultural Experiment Station Bulletin No. 362, "Mechanical Corn Pickers in Indiana", gave data on comparative costs, losses, power and labor requirements, capacities of machines, and use of corn pickers in Indiana.

Johnston and Myers (42) in University of Illinois Agricultural Experiment Station Bulletin No. 373, "Harvesting the Corn Crop in Illinois", September, 1931, gave comparative data on the different methods of harvesting corn, including costs, losses, labor and power requirements under Illinois conditions.

In summary, the "Review of Literature" has indicated a vast amount of study on the combine and grain harvesting methods, also on the corn picker and corn harvesting methods. The most helpful of these data were found in articles of agricultural periodicals, machinery periodicals, United States Department of Agriculture publications, and state agricultural experiment station literature. However, there was a need for information on the losses due to opening fields for combining by the various methods common to Central Iowa, the power requirements for transporting the machines and operating their various units, and the extent of the value of high performance features of self-propelled agricultural machines which will justify their use in sections of the country similar to Central Iowa.

THE INVESTIGATION

Specific Objectives

The review of the past studies indicates that there are insufficient data pertaining to some major points in the problem, such as losses due to opening fields for combining and picking corn, the power requirements to propel and operate the harvesting mechanism of these machines, and the extent of the value of high performance features of self-propelled agricultural machines. If we are to determine the conditions under which a high-priced machine will lower production costs, this information is vital in the investigation.

The specific objectives:

1. To determine comparative efficiencies of pull-type and self-propelled combines by determining harvesting losses chargeable to each, including field-opening losses
2. To determine the area and percentage of the fields affected by opening fields with pull-type combines, mowers, and windrowers
3. To determine power requirements of each type of machine
4. To determine labor requirements for unit production by each type of machine

5. To determine costs per unit of production for each type of machine
6. To determine the acreages at which the harvesting costs for the pull-type and self-propelled machines would be comparable

Method of Procedure for Checking Combine Losses

The procedure in this study followed the general order of the specific objectives as listed. The method of sampling was somewhat modified from those previously used, but adequate to give accurate results, and yet practical so the individual farmers will be able to check their combine in the field. Details of the equipment used will be discussed in the subheadings.

The machinery used in this investigation was an Allis-Chalmers 60-inch pull-type combine with an auxiliary mounted engine, a Massey-Harris 84-inch self-propelled combine, an Allis-Chalmers 6-foot side-delivery windrower, and an 8-foot, push-type side-delivery windrower mounted on the rear of a Ford tractor (developed by the Iowa State College Agricultural Engineering Department), and a 7-foot tractor mower used on a Ford tractor for opening fields. The above equipment is owned by Iowa State College. The tests in this study were run on oat fields of the College Service Farms.

Method of sampling

Where time and facilities would permit, the method of Stratified Random Sampling was used. By this method the field was divided into a number of equal sections or strata and marked by setting tall stakes along the boundaries. The sampling stations were located randomly and marked with tall stakes. In cases where time and facilities would not permit, the samples were taken randomly in the field and marked in the same manner as before. The entire field in this case was used as a single stratum. The 7-foot strip around the field, where grain was mashed down in the opening process by the tractor wheels, was divided into equal-length units and two samples taken from each unit or stratum. Paper bags of different sizes were used to hold the samples and labeled and numbered so they could be identified easily when the samples were weighed and recorded.

Grain losses

Grain losses are of two classes; shatter loss and harvesting losses. Harvesting losses include opening loss, windrower loss, and combining losses.

Shatter loss. Shatter loss is grain shattered on the ground, caused by wind, rain, or other forces; and varies with the kind, variety, and maturity stage of the grain. Shatter-loss samples were obtained by entering the field, prior to windrowing or combining, with an open-side frame .0001 acre in area and carefully laying it down at, or near, the sampling station. All of the grain within the frame was picked up and put in the bag marked "Shatter Loss" and numbered to correspond to the station. These samples were later weighed in grams. The general formula which was used, in the study, for converting to bushels per acre is:

$$\frac{\text{Total grams (all samples)}}{\text{No. of samples} \times \text{area of sample} \times 453.5 \times 32} = \text{bu/acre}$$

<u>Opening loss</u>. Opening loss is the loss of grain due to making the initial cut around the field with the pull-type combine, windrower or mower. In many cases in the Corn Belt and similar areas all sides of the field have to be opened in this manner due to fences, tall crops, or other obstructions. The loss is in the form of mashed-down grain, shattered grain, and clipped heads that cannot be thrown on the canvas by the reel or picked up by the pickup attachment. These samples were taken by going around the strip to the stations previously marked and taking a frame, 7 feet wide and 1 foot, 2-15/16 inches long or .0002 acre in area, which is wide enough to cover the tractor tread, and laying it across the mashed strip and removing all of the heads of bent-over stalks, picking up all clipped heads, and gathering up all of the loose grain within its boundaries and placing in an opening sample bag. These are gross opening loss

samples. For opening with a pull-type combine, the net opening loss is-- gross opening loss minus (cutter-bar loss plus shatter loss). When the field is opened with a mower or a windrower the net opening loss is--gross opening loss minus (windrower loss plus shatter loss). The same general formula is used to convert these losses to bushels per acre.

Windrower loss. Windrower loss is grain lost due to the windrowing operation. For the 6-foot windrower, the samples were taken by using a frame 6 feet wide and 2 feet long, inside measurement. This was the width of the cut swath, and by laying the frame across the swath at, or near to, each sampling station, by first laying the windrow back, all of the grain was picked up within its boundaries. The area of this sample was .000276 acre. The same general formula was used for calculating bushels per acre. These samples are gross windrower loss. The net windrower loss is gross windrower loss minus shatter loss.

Combining losses

Combining losses are incurred by the normal combining operation and are influenced by a number of factors. Improper adjustment of the combine mechanism such as the cylinder and concave clearance, cylinder speed, air blast, cutter-bar height, and reel. The speed of travel of the combine, the maturity and moisture condition of the grain, and the kind and variety of grain are also factors that affect the amount of loss. The two types of combines operating under the same conditions and each in proper adjustment should produce the same quality of product with comparable losses. These losses are termed threshing or cylinder, separating or rack and shoe, and cutter-bar or pickup losses.

Threshing loss. Loss due to threshing is in the form of unthreshed or partially threshed heads passing through the threshing mechanism and being blown over with the straw. For checking this loss a canvas strip 4.3 feet by 9 feet was used. For stretching the canvas and making it easier to handle, 2-by-2 inch strips were nailed to the canvas on the narrow sides. In checking losses from the self-propelled combine the canvas was slipped under the machine while it was stopped about 60 feet ahead of the sampling stake. The two men held the canvas under the machine and followed along until they were even with the stake and dropped the canvas to the ground and held it tightly stretched until the combine passed over. The straw and grain caught on the canvas were removed and each was put in a sample bag. In the case of the pull-type combine, where the straw is delivered to the side, the canvas was spread behind the tractor while the unit was in motion and the combine allowed to pass over it. Samples were taken from the self-propelled combine while harvesting oats from windrows produced by a 6-foot windrower, an 8-foot windrower, and while combining standing grain. The sample sizes were .000593 acre, .00079 acre, and .00069 acre, respectively. Samples were taken from the pull-type combine only while harvesting oats from the 6-foot windrow. This sample size was .000593 acre. The same general formula was used, and by substituting these sample sizes the results were in bushels per acre. All of the results of threshing loss were net loss.

Separating loss. Separating loss occurs at two places; namely, at the shoe over the sieves due to too much air, clogged sieves, and too much chaff, and over the straw rack due to an overloading of straw, rack speed too high or too low, and too much chaff. In some checks it would be necessary to take samples at both places, but it would require four men with two canvases and the sampling would be more difficult. One canvas would be held up under the straw chute and the other down under the combine to catch the shoe loss. For this investigation the total separating loss was used. The rack loss is the loose grain that remains in the straw and could be caught on the extra canvas. In checking total separating loss, the straw was shaken well over the canvas to remove all of the loose grain. The grain was then taken from the canvas and placed in the separating loss sample bags. The sample sizes for separating loss were the same as those above for threshing loss, and the same formulae were used. The results in bushels per acre are net separating loss.

Cutter-bar or pickup loss. The cutter-bar loss is the loss due to the action of the cutter bar and reel on the grain while combining standing grain. It may be in the form of both shattered grain and broken-off heads. Pickup loss is due to the action of the windrow pickup attachment on the grain. This loss is found in the form of shattered grain, broken-off heads, and sometimes bunches of heads that are down where the fingers cannot reach them. Often, in very heavy windrows, bunches are left due to an overload on the fingers. When checking the pull-type combine, where the straw is delivered to the side, the sample can be taken directly behind the combine, but in checking straight-through types like the self-propelled and the straight-through pull-types the samples must come from under the canvas. For sample size in sampling windrowed grain a frame as wide as the windrower swath was used in order to get a true sample due to the shatter and windrower losses already on the ground. For a 6-foot swath a frame 2 feet by 6 feet, or .000277 acre, was used and on the 8-foot swath a frame 2 feet by 8 feet, or .000369 acre, was used. In some cases on the 8-foot swath a frame 1 foot by 8 feet, or .0002 was used. When combining standing grain, where the grain is not concentrated in a windrow, the .0001 acre frame may be used to take the cutter-bar loss samples, but the samples should be taken randomly in the area underneath the canvas when checking the straight-through combines, and behind the combine when checking the type that delivers the straw to the side. The same general formula is used for converting the samples to bushels per acre. These losses are gross cutter-bar and pickup losses. Net pickup loss is--gross pickup loss minus (shatter plus windrower loss). Net cutter-bar loss is--gross cutter-bar loss minus shatter loss.

Net yield sampling

In order to compute gross yield and percentages of loss, the yield per acre must be known. The net yield was determined by taking samples from the grain spout for a given area. Stakes were set 10 feet apart in some cases and 12 feet apart in others on the outside of the sampling stakes. The same distance was used throughout each field. Grain was caught from the tank elevator spout as the combine moved between the previously set stakes at the sampling stations on the round prior to the one when combining loss samples were taken. In the case of the windrowed grain the area would be the width of the windrower swath times the length, and in combining standing grain it would be the width of cut of the combine times the distance between the stakes. When combining oats from the windrow made by the 6-foot windrower, a 12-foot space between stakes was used, which made the area .00165 acre. When combining from the swath made by the 8-foot windrower a distance between stakes of 10 feet was used, which made the area .00184 acre. When combining standing grain with the self-propelled combine, a width of cut of 7 feet times a distance of 10 or 20 feet between stakes made the sample area .00161 acre. These samples were weighed in pounds, so the formula for converting the results to bushels per acre is:

$$\frac{\text{Total pounds (all samples)}}{\text{No. of samples x } \begin{array}{c}.00165 \\ \text{or } .00184 \\ \text{or } .00161\end{array} \text{ x } 32} = \text{bu/acre}$$

The result of this calculation is expressed in bushels per acre and it is net yield. Gross yield is--net yield plus total loss per acre. After a group of samples were collected, they were taken to the laboratory, cleaned of all chaff and foreign material and weighed. The weights were taken by the use of balances calibrated in grams and tenths of a gram. The yield samples were weighed on scales calibrated in pounds, ounces, and one-quarter ounces. The weights were then recorded on special record sheets. The results of these tests will be found in tables under the Presentation of Data.

Presentation of Data

The grain harvesting operation in the United States

The grain harvesting operation in the United States is one of great magnitude and is distributed throughout the forty-eight states. In order to cope with the problem of losses due to weather conditions, it is necessary that the farmer have available a surplus of the types of machines used in harvesting various crops and particularly those in small grain harvesting.

The method of harvesting will vary throughout the country with the acreage of grain, size of fields, topography, machinery already on the farm or in the community, weather conditions, maturing conditions, yields, weed infestation, and other similar factors.

Tables 1 to 10 inclusive present the picture of the grain harvesting problem and how machinery companies and the farmer are coping with it. Tables 1, 2, and 3 present a summary of the grain production in the United States and a breakdown of the oat and corn production, the two most widely distributed grain crops. Table 4 presents a breakdown of the harvesting methods used on small grain over the United States in 1945, and Tables 5 and 6 the methods used in Central Iowa where this study was made. Tables 7 and 8 show the response of the machinery companies to the grain harvesting machinery needs of the farmer over a twenty-one year period. Tables 9 and 10 present a breakdown of the distribution of combines and corn pickers by states.

Grain produced in the United States

Small grain as referred to in this investigation will include wheat, oats, barley, rye, flaxseed, buckwheat, and rice. The small grain of most importance in the Corn Belt and the other sections similar is oats.

Table 1

Total Acres of Grain Harvested in the United States[a]

Region	1935-39 average 1000 acres	1940-44 average 1000 acres	1945 1000 acres
Northeast	4,533	4,252	4,081
Corn Belt	23,880	19,879	19,714
Lake States	15,646	14,216	14,109
Great Plains	36,082	42,321	47,149
Appalachian	1,454	1,408	1,486
Southeast	3,012	3,451	3,772
Delta States	1,092	1,545	1,851
Oklahoma-Texas	10,818	11,112	15,206
Mountain	7,754	9,713	10,868
Pacific	6,169	6,386	6,868
United States	110,440	114,283	125,062

[a]Information in this table was taken from A. P. Brodell, J. S. Birkhead, and J. H. Peters, Bureau of Agricultural Economics, U.S.D.A. Article in Farm Improvement News, Harvesting Small Grain and Utilization of the Straw, September 11, 1947

Table 2

Total Acres of Oats Harvested in United States[a]

Region	1938-1947 average 1000 acres	1948 1000 acres	1949 1000 acres
New England	154	128	153
Middle Atlantic	1,609	1,516	1,644
East North Central	9,652	10,707	11,213
West North Central	19,589	21,714	20,820
South Atlantic	1,783	1,598	1,885
East South Central	763	857	788
West South Central	3,192	2,207	2,480
Mountain	979	900	923
Pacific	624	571	654
United States	38,347	40,198	40,560
U. S. yield (bu/acre, av)	32.1	37.1	32.6

[a]Information in this table was taken from Statistical Abstracts of the United States, 1950, U. S. Dept. of Commerce, Bureau of the Census, Table 733, page 619, Oats - Acreage, Production and Value, by States, 1938 to 1949.

Table 3

Total Acres of Corn Harvested in United States[a]

Region	1938-1947 average 1000 acres	1948 1000 acres	1949 1000 acres
New England	188	160	169
Middle Atlantic	2,226	2,277	2,264
East North Central	19,994	21,960	22,006
West North Central	34,280	35,015	36,224
South Atlantic	11,621	9,607	9,590
East South Central	10,799	9,662	9,298
West South Central	8,970	6,201	5,907
Mountain	1,420	1,074	1,158
Pacific	145	111	119
United States	88,617	86,067	86,735
U. S. yield (bu/acre, av)	31.4	42.8	38.9

[a]Information in this table was taken from Statistical Abstracts of the United States, 1950, U. S. Dept. of Commerce, Bureau of the Census, Table 727, page 615, Corn - Acreage, Production, and Value, by States, 1938 to 1949.

Methods of harvesting grain

Since the introduction of the combine, the method of harvesting small-grain crops has changed until two-thirds of these crops are harvested with the combine. Where there is a large amount of weed growth in small grain and uneven maturing of the grain it seems more profitable to windrow. It is also necessary to windrow such crops as flax seed and some of the clovers. Table 4 summarizes the percentages of small-grain crops harvested by specific methods in 1945.

Table 4

Percentage of Small Grain Crops Harvested by Specified Method

Region	1945 combined		Threshed with stationary thresher or cut and fed unthreshed, per cent
	As standing grain per cent	From windrow per cent	
Northeast	36.5	0.2	63.3
Corn Belt	46.0	11.0	43.0
Lake States	14.7	12.3	73.0
Great Plains	47.9	18.0	33.2
Appalachian	32.8	----	67.2
Southeast	44.0	----	56.0
Delta States	38.2	----	61.8
Oklahoma-Texas	82.1	----	17.9
Mountain	72.2	2.0	25.8
Pacific	91.0	2.4	6.6
United States	51.7	10.6	37.7

Information for this table was taken from A. P. Brodell, J. W. Birkhead, and J. H. Peters, Bureau Agricultural Economics, U.S.D.A., article in Farm Imp. News, Harvesting Small Grain and Utilization of the Straw. September 11, 1947.

Table 5

Results of Survey to Determine Percentage of Oats Harvested by Various Methods in Central Iowa Trip made to Fort Dodge by E. R. Johnson and E. L. Barger, July 25, 1948 (33)

Method of harvesting	Combined windrowed	Combined standing	Binder cut & shocked	Uncut	Method undetermined
No. fields	48	10	56	18	55
% fields	25.7	5.3	30.0	9.6	29.4
Acres	1355	400	1640	415	1510
% acres	25.5	7.5	30.8	7.8	28.4
% fields	42.0	8.8	49.2	----	----
% acres	40.0	12.0	48.0	----	----

Table 6

Results of Survey to Determine Percentage of Oats Harvested by Various Methods in Central Iowa Trip to Allentown by E. R. Johnson and E. L. Barger, July 22, 1948 (33)

Method of harvesting	Combined windrowed	Combined standing	Binder cut & shocked	Uncut	Method undetermined
No. fields	108	10	78	65	0
% fields	41.4	3.8	29.9	24.9	0
Acres	2350	355	1670	1290	0
% acres	41.5	6.25	2.95	22.75	0
% fields	55.0	5.10	39.90	--	-
% acres	53.7	8.10	38.20	--	-

Harvesting equipment produced

Table 7 contains a tabulation of the small grain harvesting equipment that has been produced by the machinery companies since 1929.

Table 7

Harvesting Machinery Produced for the Period 1929 to 1949[a]

Year	Binders	Combines All types	Combines Pull	Combines S. P.	Threshers	Wind-rowers
1929	65,069	36,957	---	0	13,812	0
1939	0	41,537	---	0	2,781	0
1940	0	46,552	---	0	2,054	0
1941	0	54,296	---	0	2,459	0
1942	0	41,722	---	0	2,146	0
1943	3,782	29,219	---	0	668	0
1944	10,817	44,704	43,604	1,100	1,858	1,570
1945	9,054	54,162	48,131	3,287	1,185	2,744
1946	---	51,010	45,701	3,110	2,585	2,199
1947	9,523	76,638	71,132	5,506	1,277	3,961
1948	0	90,668	80,470	10,198	2,161	8,875
1949	0	104,888	91,217	13,671	2,062	12,646

[a]Information for this table was taken from Farm Implement News tabulation and article "How Big Can An Oyster Grow?". 69:104-110, July 1, 1948, and Farm Equipment Production by Classes, 1929-1949, Farm Implement News, 71:124-129, July 10, 1950.

Table 8

Corn Harvesting Machines Produced in the United States for the Period 1929 to 1949[a]

Year	Binders	Corn pickers	Row-type ensilage harvesters
1929	15,246	0	0
1939	5,535	16,044	0
1940	9,990	11,638	0
1941	13,175	15,958	0
1942	0	13,640	0
1943	3,077	12,592	237
1944	9,709	25,371	3,032
1945	8,699	35,885	4,116
1946	7,218	35,552	7,034
1947	0	66,065	15,353
1948	0	78,808	17,304
1949	0	90,410	19,357

[a]Information for this table was taken from Farm Implement News tabulation and article "How Big Can an Oyster Grow?", 69:104-110, July 1, 1948, and Farm Equipment Production by Classes, 1929-49, 71:124-129, July 10, 1950.

Combines on farms

Table 9 gives a tabulation of the number of combines on the farms in the United States by states according to the 1945 Census and Estimate for January 1, 1950.

Table 9

Combines on Farms 1945 - 1950[a]

State	No. of combines 1945	No. of combines 1950	State	No. of combines 1945	No. of combines 1950
Alabama	2,148	4,500	Nebraska	20,591	30,000
Arizona	463	600	Nevada	154	200
Arkansas	3,410	8,000	New Hampshire	226	300
California	4,529	6,300	New Jersey	875	1,800
Colorado	7,188	10,500	New Mexico	1,721	3,300
Connecticut	232	290	New York	5,853	11,000
Delaware	472	1,100	N. Carolina	4,934	10,000
Florida	242	500	N. Dakota	23,261	33,000
Georgia	3,629	7,000	Ohio	19,545	39,000
Idaho	5,179	11,000	Oklahoma	15,976	27,000
Illinois	38,470	65,000	Oregon	5,761	7,200
Indiana	17,720	38,000	Pennsylvania	7,436	14,400
Iowa	23,678	41,000	Rhode Island	8	10
Kansas	48,067	66,000	S. Carolina	2,022	6,000
Kentucky	2,422	7,000	S. Dakota	10,831	18,000
Louisiana	1,675	4,500	Tennessee	2,969	6,000
Maine	458	500	Texas	15,656	31,000
Maryland	1,465	2,800	Utah	937	2,000
Massachusetts	290	300	Vermont	457	500
Michigan	12,920	21,500	Virginia	3,044	6,500
Minnesota	16,021	22,000	Washington	5,881	9,500
Mississippi	2,953	6,500	W. Virginia	331	500
Missouri	11,127	22,000	Wisconsin	8,972	13,500
Montana	10,708	18,500	Wyoming	2,089	4,000
			UNITED STATES	374,785	640,000

[a]Information for this table was taken from Farm Implement News tabulation and article "Machinery on Farms 1950", 71:83-92, July 10, 1950

Corn pickers on farms

Table 10 gives a tabulation of the number of corn pickers on the farms in the United States by states according to the 1945 Census and Estimate for January 1, 1950.

Table 10

Corn Pickers on Farms 1945 - 1950[a]

State	No. of pickers 1945	1950	State	No. of pickers 1945	1950
Alabama	85	600	Nebraska	7,000	34,000
Arizona	2	10	Nevada	0	0
Arkansas	130	800	New Hampshire	9	10
California	185	275	New Jersey	290	1,100
Colorado	400	1,950	New Mexico	4	25
Connecticut	10	30	New York	285	1,200
Delaware	70	600	N. Carolina	280	2,100
Florida	4	100	N. Dakota	1,830	4,000
Georgia	75	800	Ohio	12,000	33,000
Idaho	75	150	Oklahoma	400	2,500
Illinois	37,700	67,000	Oregon	75	100
Indiana	15,700	41,000	Pennsylvania	1,350	9,000
Iowa	44,800	80,000	Rhode Island	7	10
Kansas	2,100	10,000	S.Carolina	40	600
Kentucky	570	2,500	S. Dakota	7,840	20,000
Louisiana	60	400	Tennessee	595	1,200
Maine	5	10	Texas	750	3,500
Maryland	250	2,000	Utah	3	15
Massachusetts	10	20	Vermont	8	20
Michigan	2,850	13,000	Virginia	315	3,000
Minnesota	20,000	36,000	Washington	20	25
Mississippi	100	800	W. Virginia	50	200
Missouri	3,500	15,000	Wisconsin	4,000	11,000
Montana	190	250	Wyoming	35	100
			UNITED STATES	168,057	400,000

[a]Information for this table was taken from Farm Implement News tabulation and article "Machinery on Farms 1950", 71:83-92, July 10, 1950

Combining losses, self-propelled combine, from windrow

Table 11 is a tabulation of the losses incurred by opening the field with a 7-foot mower on a Ford tractor. The oats were windrowed with a 6-foot Allis-Chalmers side-delivery windrower, and combined with a Massey-Harris 84-inch self-propelled combine early in the season, July 22, 1948. The original sampling data are in Table 30 in the Appendix.

Table 12 is a tabulation of the losses incurred by opening the field with the Allis-Chalmers 6-foot side-delivery windrower (outside cut first), and windrowed with same. The original sampling data are in Table 31 in the Appendix. This combining was done in late season, July 15, 22, 23, 1949.

Table 13 is a tabulation of the harvesting losses incurred by opening the field with the 8-foot push-type, rear-mounted windrower, developed by the Agricultural Engineering Department, Iowa State College, mounted on a Ford tractor and windrowing with the same machine. This was done in late season, July 27 and August 3, 1948. The original sampling data are in Table 32 in the Appendix.

Table 11

Harvesting Losses - Massey-Harris Self-Propelled 84" Combine
Field opened with 7' tractor mower; windrowed,
A. C. 6' commercial windrower
Swine Breeding Farm, Field 5. Ac. 396'x550'. July 22, 1948.

Type loss	Loss lbs/acre	Loss bu/acre	Loss percent
Shatter	7.05	0.220	0.382
Opening[a]	48.50*	1.515*	2.632*
Windrower[b]	53.22	1.663	2.889
Threshing	15.55	0.486	0.843
Separating	36.24	1.132	1.968
Pickup[c]	38.90	1.215	2.110
Total loss/acre	199.46	6.231	10.824
Net yield/acre	1642.57	51.330	89.176
Gross yield/acre	1842.03	57.561	100.000

[a]Opening losses are net (Opening losses - (sh + wr))

[b]Windrower losses are net (Wr - shatter)

[c]Pickup losses are net (Pickup - (sh + wr))

*These figures represent the opening losses per acre spread over the 5-acre field. The affected area of this field was 0.295 acre with a loss of 25.6 bu/acre, or 44.61 per cent.

Table 12

Harvesting Losses - Massey-Harris 84" Self-Propelled Combine from Windrow. Field opened (outside cut first) and windrowed with Allis-Chalmers 6' commercial pull-type windrower.
Dairy Farm, 18.1 acres. July 15, 22, 23, 1949.

Type loss	Loss lbs/acre	Loss bu/acre	Loss percent
Shatter	16.30	0.509	0.87
Opening[a]	13.50*	0.422*	0.72*
Windrower[b]	207.50	6.484	11.02
Threshing	3.30	0.103	0.19
Separating	36.00	1.125	1.92
Pickup[c]	431.00	13.468	22.88
Total loss/acre	708.60	22.111	37.70
Net yield/acre	1176.00	36.750	62.40
Gross yield/acre	1884.60	58.861	100.00

[a]Opening losses are net (Gross O. L. - (sh + wr))

[b]Windrower losses are net (Gross wr - shatter)

[c]Pickup losses are net (Gross pickup - (sh + wr))

*These figures represent the opening losses per acre spread over the 18.1-acre field. The affected area of this field is 0.403 acre with a loss of 18.94 bu/acre, or 32.2 per cent.

Table 13

Harvesting Losses - Massey-Harris Self-Propelled 84" Combine
Field opened with 8' push-type mounted windrower.
Atomic Energy Farm, Field 11.3. Ac. 365'x1360'. Opened 3 sides. Affected area 464 acres. July 27 and August 3, 1948.

Type loss	Loss lbs/acre	Loss bu/acre	Loss percent
Shatter	68.80	2.150	4.609
Opening[a]	0.09*	0.003*	0.006*
Windrower[b]	114.33	3.573	7.660
Threshing	1.54	0.048	0.103
Separating	37.30	1.165	2.497
Pickup[c]	128.44	4.014	8.605
Total loss/acre	350.50	10.953	23.480
Net yield/acre	1142.08	35.690	76.520
Gross yield/acre	1492.58	46.643	100.000

[a]Opening losses are net (Gross O. L. - (sh + wr))

[b]Windrower losses are net (Gross wr - shatter)

[c]Pickup losses are net (Gross P. L. - (sh + wr))

*These figures represent the opening losses per acre spread over the 11.3-acre field. The affected area of this field was 0.464 acre with a loss above normal windrower loss and shatter loss of 0.067 bu/acre of 0.14 per cent.

Fig. 15. Oat Field Opened for Combining with 8' Rear-Mounted Windrower (Single Windrow)

Fig. 16. Oat Field Opened for Combining with 8' Rear-Mounted Windrower (Double Windrow)

Fig. 17. Servis Recorder Used to Determine Operating Time of Combines

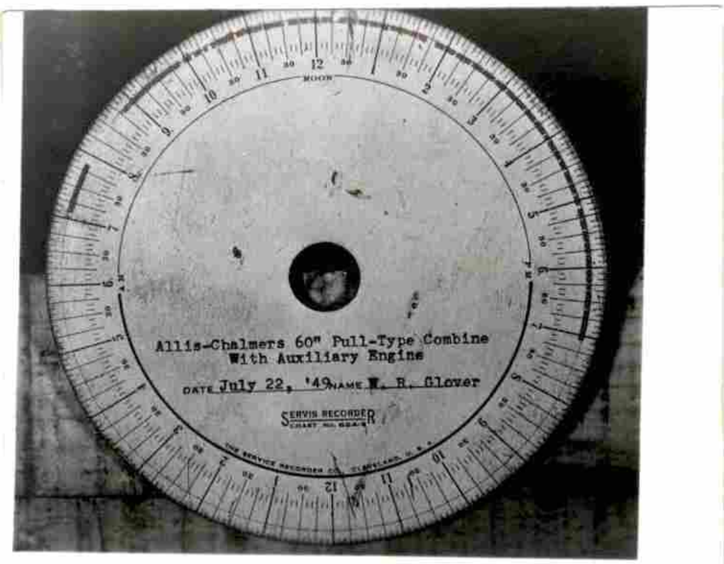


Fig. 18. Servis Recorder Chart Showing Details of a Day's Operation Time of a Combine Including Travel and Servicing Time

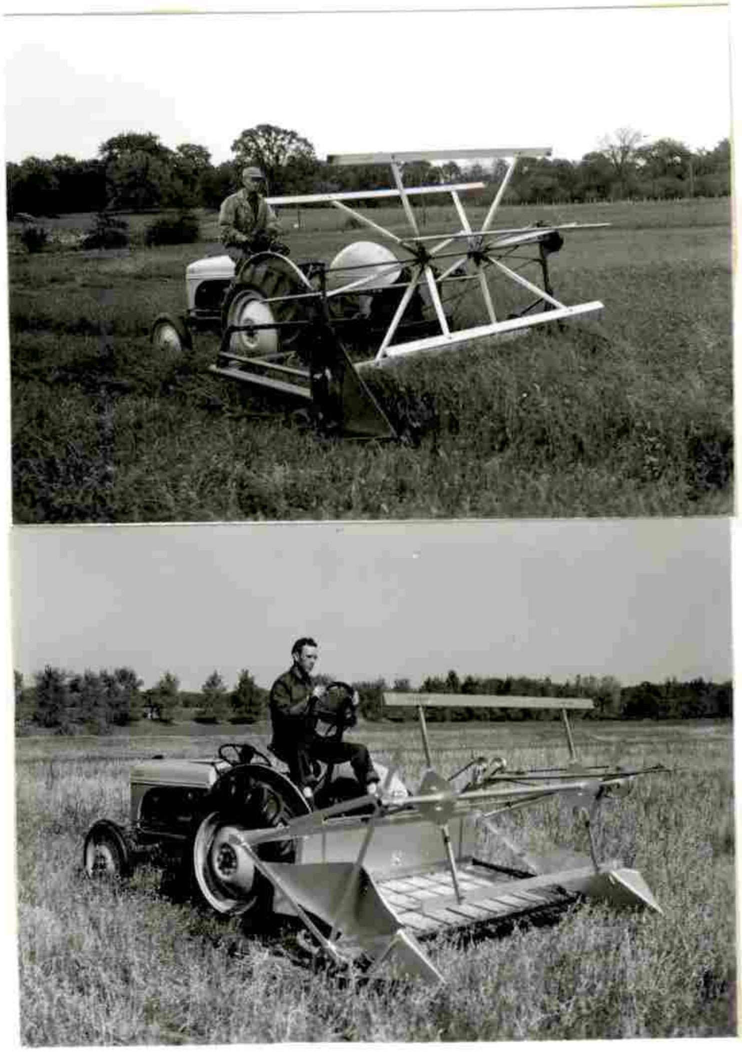


Fig. 19. Iowa State College's 8'
Rear-Mounted Windrower, 1948

Combining losses, self-propelled combine, standing grain

Table 14 is a tabulation of the losses incurred by combining standing grain with the Massey-Harris 84-inch self-propelled combine late in the season, July 30, 31 and August 2, 1948. The original sampling data are in Table 33 in the Appendix.

Table 14

Harvesting Losses - Massey-Harris Self-Propelled 84" Combine
Combining standing grain. Animal Husbandry Farm, Field 21.

Type loss	Loss lbs/acre	Loss bu/acre	Loss percent
Shatter	217.410	6.790	11.065
Cutter-bar[a]	441.040	13.780	22.457
Threshing	0.577	0.018	0.029
Separating	53.600	1.675	2.729
Total loss/acre	712.627	22.263	36.280
Net yield/acre	1249.500	39.097	63.720
Gross yield/acre	1962.127	61.360	100.000

[a]Cutter-bar losses are net (gross cutter-bar - shatter)

Table 15 is a tabulation of the losses incurred by combining standing grain with the Massey-Harris 84-inch self-propelled combine about mid-season, July 13, 14, 15, 1949. The original sampling data are in Table 34 in the Appendix.

Table 15

Harvesting Losses - Massey-Harris 84" Self-Propelled Combine
Combining standing grain. Animal Husbandry Farm, 31.2 acres.
July 13, 14, 15, 1949

Type loss	Loss lbs/acre	Loss bu/acre	Loss percent
Shatter	13.20	0.413	0.60
Cutter bar[a]	161.40	5.043	7.35
Threshing	1.13	0.035	0.05
Separating	107.20	3.350	4.87
Total loss/acre	282.93	8.841	12.87
Net yield/acre	1914.50	59.828	87.13
Gross yield/acre	2197.43	68.669	100.00

[a]Cutter-bar losses are net (gross cutter-bar - shatter)

Fig. 20. Windrowing Oats with Allis-Chalmers 6' Pull-Type Windrower

Fig. 21. Combining Oats from 6' Windrower with Allis-Chalmers 60" Pull-Type Combine with Auxiliary Mounted Engine

Fig. 22. Combining Standing Oats with Massey-Harris 84" Self-Propelled Combine

Fig. 23. Combining Lodged Oats with Massey-Harris 84" Self-Propelled Combine

Combining losses, pull-type combine, from windrow

Table 16 is a tabulation of the losses incurred by opening the field with a 7-foot mower on a Ford tractor, and windrowing with the 6-foot Allis-Chalmers side-delivery windrower. The combining was with the Allis-Chalmers 60-inch pull-type combine pulled with the Allis-Chalmers "WD" tractor, in mid-season, July 22, 1948. The original sampling data is in Table 30 in the Appendix.

Table 17 is a tabulation of the losses incurred by opening the field and windrowing with the Allis-Chalmers 6-foot side-delivery windrower and combining from the windrow with the Allis-Chalmers 60-inch pull-type combine pulled with the Allis-Chalmers "WD" tractor, in early season, July 7, 9, 11, and 12, 1949. The original sampling data are in Table 35 in the Appendix.

Table 18 is a tabulation of the losses incurred by opening the field with the 8-foot rear-mounted windrower, single windrow, and windrowed with the Allis-Chalmers 6-foot side-delivery windrower. Oats were combined from the windrow with the Allis-Chalmers 60-inch pull-type combine pulled with the Allis-Chalmers "WD" tractor, in early season, July 11, 13, 1949. The original sampling data are in Table 36 in the Appendix.

Table 19 is a tabulation of the losses incurred by opening the field with the 8-foot rear-mounted windrower, double

Table 16

Harvesting Losses - Allis-Chalmers Pull-Type 60" Combine
Field opened with 7' tractor mower. Windrowed,
A. C. 6' commercial windrower.
Swine Breeding Farm, Field 5. Ac. 396' x 550'.

Type loss	Loss lbs/acre	Loss bu/acre	Loss percent
Shatter	7.05	0.220	0.382
Opening[a]	48.50*	1.515*	2.632*
Windrower[b]	53.22	1.663	2.889
Threshing	2.67	0.083	0.144
Separating	33.86	1.058	1.838
Pickup[c]	58.83	1.832	3.187
Total loss/acre	204.13	6.376	11.072
Net yield/acre	1637.90	51.185	88.928
Gross yield/acre	1842.03	57.561	100.000

[a]Opening losses are net (Gross O. L. - (sh + wr))

[b]Windrower losses are net (Gross wr - shatter)

[c]Pickup losses are net (Gross P. L. - (sh + wr))

*These figures represent the opening losses per acre spread over the 5-acre field. The affected area of this field was 0.295 acre with a loss of 25.6 bu/acre, or 44.61 per cent.

Table 17

Harvesting Losses - Allis-Chalmers 60" Pull-Type Combine. Opened four sides and windrowed with Allis-Chalmers 6' commercial pull-type windrower. South 450 farm, 11 acres. July 7, 9, 11, 12, 1949.

Type loss	Loss lbs/acre	Loss bu/acre	Loss percent
Shatter	9.50	0.296	0.57
Opening[a]	28.80*	0.900*	1.74*
Windrower[b]	44.20	1.381	2.67
Threshing	2.80	0.087	0.17
Separating	22.90	0.715	1.38
Pickup[c]	68.10	2.128	4.12
Total loss/acre	176.30	5.507	10.65
Net yield/acre	1479.30	46.225	89.35
Gross yield/acre	1655.60	51.732	100.00

[a]Opening losses are net (gross o. l. - (sh + wr))

[b]Windrower losses are net (gross wr - shatter)

[c]Pickup losses are net (gross pickup - (sh + wr))

*These figures represent the opening losses per acre spread over the 11-acre field. The affected area of this field is 0.46 acre with a loss of 21.48 bu/acre, or 41.4 per cent.

Table 18

Harvesting Losses - Allis-Chalmers 60" Pull-Type Combine
Field opened with 8' rear-mounted windrower. Single windrow.
Windrowed, Allis-Chalmers 6' commercial windrower.
Swine Breeding Farm, 7.31 acres. July 11, 13, 1949.

Type loss	Loss lbs/acre	Loss bu/acre	Loss percent
Shatter	28.8	0.900	1.21
Opening[a]	3.8*	0.119*	.16*
Windrower[b]	34.7	1.084	1.46
Threshing	18.3	0.572	.77
Separating	108.0	3.343	4.52
Pickup[c]	376.5	11.765	15.83
Total loss/acre	570.1	17.783	23.95
Net yield/acre	1808.7	56.522	76.05
Gross yield/acre	2378.8	74.305	100.00

[a]Opening losses are net (gross o. l. - (sh + wr))

[b]Windrower losses are net (gross wr - shatter)

[c]Pickup losses are net (gross pickup - (sh + wr))

*These figures represent the opening losses per acre spread over the 7.31-acre field. The affected area of this field was 0.364 acre with a loss of 2.49 bu/acre, or 3.24 per cent.

Table 19

Harvesting Losses - Allis-Chalmers 60" Pull-Type Combine Opened three sides with 8' rear-mounted windrower. Double windrow. Windrowed, Allis-Chalmers 6' commercial windrower. East 450 farm, 32.1 acres. July 8, 18, 19, 20, 21, 1949.

Type loss	Loss lbs/acre	Loss bu/acre	Loss percent
Shatter	9.10	0.284	0.40
Opening[a]	4.65*	0.145*	0.21*
Windrower[b]	66.50	2.073	2.94
Threshing	3.10	0.097	0.13
Separating	50.70	1.584	2.25
Pickup[c]	140.40	4.387	6.22
Total loss/acre	274.45	8.570	12.15
Net yield/acre	1984.40	62.012	87.85
Gross yield/acre	2258.85	70.582	100.00

[a]Opening losses are net (gross o. l. - (sh + wr))

[b]Windrower losses are net (gross wr - shatter)

[c]Pickup losses are net (gross pickup - (sh + wr))

*These figures represent the opening losses per acre spread over the 32.1-acre field. The affected area of this field is .59 acre with a loss of 7.9 bu. per acre, or 11.2 per cent.

Fig. 24. Picking Corn with Pull-Type Picker

Fig. 25. Picking Corn with Massey-Harris Self-Propelled Corn Picker

windrow, and windrowed with the 6-foot Allis-Chalmers side-delivery windrower and combined with the Allis-Chalmers 60-inch pull-type combine in mid-season, July 8, 18, 19, 20, 21, 1949. The original sampling data are in Table 37 in the Appendix.

Grain losses due to opening fields for combining by different methods and total grain losses on the initial cut

Table 20 is a tabulation of the grain losses contributed to opening fields by the common methods used in Central Iowa. The per cent loss chargeable to the opening operation is listed in the first column. This opening loss spread over the entire acreage is listed in the second column and the total grain loss, including shatter loss, is entered in the last column. The last item listed "Massey-Harris S. P. 84-inch (Late)" had an unusually high loss due to the cutter bar and reel action on the over-ripe grain.

Grain losses by methods of harvesting and types of losses

Table 21 is a tabulation of the grain losses by methods of harvesting and types of losses, in per cent of loss and includes shatter loss.

Table 20

Grain Losses due to Opening Oat Fields for Combining by Different Methods and Total Grain Loss on the Initial Cut

Method of opening	Opening loss on initial cut	Opening loss distributed over field	Total grain loss on initial cut
	%	%	%
Mower opening (7 ft tractor mower)	44.61	2.63	52.802 M.H. 53.050 A.C.
A.C. 6 ft pull-type W.R. (inside cut first) (early)	41.4	1.74	50.31
A.C. 6 ft pull-type W.R. (outside cut first) (late)	32.2	.72	69.18
Rear-mounted W.R. double W.R.	11.2	.21	23.14
Rear-mounted W.R. single W.R.	3.24	.16	27.03
Massey-Harris S.P. 84" (early)	12.27	----	12.87
Massey-Harris S.P. 84" (late)	25.215	----	36.280

Table 21

Grain Losses by Methods of Harvesting and Types of Losses

Method of harvesting	Shatter loss	Wind-rower loss	Open-ing loss	Thresh-ing loss	Sepa-rating loss	Pickup cutter-bar loss	Total loss
	%	%	%	%	%	%	%
1. With pull-type AC 60" combine; from windrow by A.C. 6 ft W.R.; opened with 7 ft mower.	0.382	2.889	44.61* 2.632	0.144	1.838	3.187	11.072
2. With pull-type AC 60" combine; from windrow by AC 6 ft W.R.; opened with 6 ft AC W.R.	0.570	2.670	41.4* 1.740	0.170	1.380	4.120	10.650
3. With pull-type AC 60" combine; from windrow by AC 6 ft W.R.; opened with rear-mounted 8 ft W.R.; single w.r.	1.21	1.46	4.83* 0.16	0.770	4.52	15.83	23.95
4. With pull-type AC 60" combine; from windrow by AC 6 ft W.R.; opened with rear-mounted W.R.; double w.r.	0.40	2.94	14.1* 0.21	0.130	2.25	6.22	12.15
5. With Massey-Harris S.P. 84" combine; from windrow by AC 6 ft W.R.; opened with 7 ft mower.	0.382	2.889	44.61* 2.632	0.843	1.968	2.110	10.824

*Opening loss on initial opening cut

(Continued on next page)

Table 21 (Cont'd)

Method of harvesting	Shatter loss	Wind-rower loss	Open-ing loss	Thresh-ing loss	Sepa-rating loss	Pickup cutter-bar loss	Total loss
	%	%	%	%	%	%	%
6. With Massey-Harris S.P. 84" combine; from windrow by AC 6 ft W.R. opened with AC 6 ft W.R. (outside cut first)	0.87	11.02	32.20* 0.72	0.190	1.920	22.88	37.70
7. With Massey-Harris S.P. 84" combine; from windrow by 8 ft rear-mounted W.R.; opened with 8 ft rear-mounted W.R.	4.609	7.660	0.14* 0.006	0.103	2.497	8.605	23.480
8. Massey-Harris S.P. 84" combine; combining standing grain early	0.600	----	----	0.050	4.870	7.350	12.870
9. Massey-Harris S.P. 84" combine; combining standing grain late	11.065	----	----	0.029	2.729	22.457	36.280

*Opening loss on initial opening cut

Performance Characteristics

The purpose of this test was for evaluating the performance characteristics of each type combine by checking the travel speed of the combines under various operating conditions, the time required for the combines to turn at corners of fields, time required to unload grain bins, and driving each machine over a 3.8-mile course which included conditions that are encountered normally on Central Iowa farms. In this last check mentioned the units were manned by operators with as near equal experience as possible on their particular machines. The two units used in this check were the Massey-Harris 84" self-propelled combine and the Allis-Chalmers 60" pull-type combine with auxiliary mounted engine pulled by an Allis-Chalmers WD tractor. The check consisted of thirteen tests numbered from "A" through "M" and were as follows:

Test A - Time required to bring machines from storage shed, service, and start traveling

Test B - Travel speed on paved highway, .8 mile, both to and from field

Test C - Travel speed downhill

Test D - Travel speed uphill

Test E - Travel speed on level road

Test F - Travel speed over 1 mile level road

Test G - Time required to enter fields through 12-foot gates from narrow farm lanes

Test H - Time required to leave fields through 12-foot gates

Test I - Time required to enter fields through double gates from narrow farm lanes

Test J - Time required to leave fields through double gates

Test K - Travel speed in narrow farm lanes

Test L - Time required to store machine in implement shed

Test M - Total elapsed time over course

The results of these performance tests have been listed in ratio per cent form using the Massey-Harris 84-inch self-propelled combine as the base for calculating percentages. The overall efficiency in performance cannot be determined by adding the percentages and comparing the sum, as each item carried a different weight and are expressed in different quantities. They may be compared by separate tests or groups of tests as shown below Tables 22 and 23 on pages 72 and 73.

Table 22

Comparison of the Performance of the Massey-Harris 84" Self-Propelled and Allis-Chalmers 60" Pull-Type Combines in Harvesting Oats

Item checked	Massey-Harris 84" s.p.	Allis-Chalmers 60"	Ratio[a] %
1. Harvesting, acres/hr	2.39	2.900	82.4
2. " bu/hr	207.00	149.000	139.0
3. " A/hr/ft width of cut	0.341	0.580	58.7
4. " bu/hr/ft width of cut	29.600	29.800	99.4
5. Unloading time, minutes	3.020	1.680	179.8
6. " " bu/min	11.200	9.300	120.6
7. Turning time, seconds	9.440	18.860	50.1

[a]Ratio = $\left(\frac{\text{M.H. s.p.}}{\text{A.C.}} \times 100\right)$ %

Items $\left.\begin{matrix}1\\3\\4\end{matrix}\right\}$ $<$ 100 not good for self-propelled

Item 5 $>$ 100 not good for self-propelled

Items $\left.\begin{matrix}2\\6\end{matrix}\right\}$ $>$ 100 good for self-propelled

Item 7 $<$ 100 good for self-propelled

Table 23

Comparison of the Massey-Harris 84" Self-Propelled and Allis-Chalmers 60" Pull-Type Combines as to Travel and Maneuverability, August 8 and 9, 1949

Item	M.H. s.p. time or mph	A.C. 60" time or mph	Ratio[a] %
Test A	15.60 min	11.812 min	131.80
Test B	5.75 mph	10.87 mph	50.30
Test C	6.19 mph	10.48 mph	59.00
Test D	5.40 mph	10.27 mph	52.60
Test E	5.23 mph	8.00 mph	65.40
Test F	6.48 mph	11.55 mph	56.10
Test G	0.126 min	1.65 min	7.53
Test H	0.074 min	1.275 min	5.85
Test I	0.042 min	0.100 min	41.70
Test J	0.057 min	0.117 min	48.70
Test K	6.67 mph	9.76 mph	68.40
Test L	0.685 min	3.47 min	19.73
Test M	1.800 hrs	1.29 hrs	139.50

[a]Ratio $= \left(\frac{\text{M.H. s.p.}}{\text{A.C.}} \times 100\right)\%$

$\text{Tests}\left.\begin{matrix}A\\M\end{matrix}\right\} > 100$ not good for self-propelled

$\text{Tests}\left.\begin{matrix}B\\C\\D\\E\\F\\K\end{matrix}\right\} < 100$ not good for self-propelled

$\text{Tests}\left.\begin{matrix}G\\H\\I\\J\\L\end{matrix}\right\} < 100$ good for self-propelled

Opening Area and Percentage of Field Affected

A survey was made by automobile of 230 fields within a 15-mile radius of Ames on August 4 and 5, 1948, on roads selected randomly. The field acres and dimensions were estimated, and the number of sides and ends of fields subject to opening determined. The initial data is in Table 44 in the Appendix. A summary of the data is given in Table 24 below.

Table 24

Opening Loss Area and Per Cent per Acre Affected by Opening Oat Fields for Combining, with Pull-Type Combines, Tractor Mowers and Commercial Pull-Type Windrowers

No. of fields	Acreage	Sides aff.	Area aff.
230	5,474.9	861	139.00
Average No. of sides to be opened per field = 3.74			
Average per cent per acre area affected = 2.54			
Average acreage per field = 23.80			

Table 25

Area and Percentage of Different Size and Shape Fields Affected by Opening with 6-foot Pull-Type Combine, Mowing Machine, or Windrower

Size field	Square		L = 1-1/2W		L = 2W		L = 3W		L = 4W	
acres	Aff. acres	% aff.	Aff. acres	% aff.	Aff. acres	% aff.	Aff. acres	% aff.	Aff. acres	% aff.
1	.125	12.50	.129	12.90	.133	13.33	.147	14.70	.158	15.85
2	.173	8.70	.185	9.24	.192	9.62	.213	10.65	.228	11.40
5	.291	5.83	.296	5.93	.309	6.20	.336	6.74	.365	7.32
10	.415	4.15	.423	4.23	.442	4.42	.479	4.79	.522	5.22
15	.512	3.40	.520	3.47	.543	3.518	.589	3.932	.639	4.27
20	.590	2.94	.603	3.01	.627	3.130	.682	3.410	.740	3.70
25	.662	2.64	.676	2.70	.700	2.800	.764	3.05	.808	3.23
30	.725	2.42	.740	2.463	.768	2.562	.837	2.790	.908	3.03
40	.840	2.10	.855	2.138	.892	2.222	.969	2.422	1.05	2.63
50	.938	1.87	.957	1.91	.996	1.990	1.086	2.173	1.174	2.35
60	1.040	1.73	1.050	1.75	1.093	1.820	1.195	1.990	1.29	2.15
80	1.178	1.472	1.220	1.520	1.260	1.575	1.373	1.720	1.49	1.86

Power Requirements

Variations in soil conditions, the amount of straw, yield, maturity of the grain, weed infestation, temperature, weight of the combine, traction devices, topography and other similar factors can and will cause wide variations in power requirements for draft and the operation of the different units of the combine. The machinery manufacturers have faced this problem by the cut-and-try method and in some cases have over-powered some of their machines in order to have ample power to get satisfactory performance even on the toughest jobs.

Since the equipment was not available to run strain-gage tests for power requirements of the different units of the combine for this study, the power requirements will be established on the basis of power units actually used in the self-propelled combines and auxiliary engines mounted on the pull-type machines, along with the tractor recommendations made by the companies. Maximum output at the recommended engine speed will be used as the power available to the machine. Table 28 is a summary of this information on both the self-propelled and pull-type combines. Tables ~~44~~ 45 and ~~45~~ 46 in the Appendix are the primary accumulations of these data. This information covers data on the 15 models of self-propelled combines that are produced by the major machinery companies, and all models of pull-type combines by sizes.

Table 26

Power Requirements of Combines[a]

Size cut width ft	Self-propelled		Pull-type	
	Total H.P.	H.P. per ft. of cut width	Total H.P.	H.P. per ft. of cut width
3.5	----	----	27.35	7.87
4.5	----	----	27.39	6.08
5.0	----	----	40.76 Av.	8.15
5.5	----	----	44.05 Av.	8.02
6.0	----	----	42.39 Av.	7.06
6.5	----	----	46.39	7.05
7.0	30.00	4.3	50.79 Av.	7.25
8.0	----	----	64.39	8.05
8.5	52.00	6.12	----	----
9.0	----	----	69.52 Av.	7.72
10.0	40.25 Av.	4.02	----	----
12-12-2/3	50.50 Av.	4.17	80.28 Av.	6.69
13-13-1/2	38.50 Av.	2.91	----	----
14	35.00	2.50	----	----
15	58.00	3.87	----	5.37
16	----	----	85.81	5.37
20	----	----	104.01	5.20
Average	45.70	3.92	58.10	6.23

[a]Information in this table was taken from Red Tractor Book, 1950-51, by Implement and Tractor, pages 378 and 379, Tractor, Farm and Industrial Engines, pages 222-248. The information concerning plow size of tractor and the average horsepower shown was taken from Illustrated Tractor Specifications 1950 Tractor Field Book by Farm Implement News.

Power recommendations for pull-type combines have been on the basis of plow sizes of tractors; for example, 1-plow, 2-plow, and this terminology has been rather hard to interpret. To clarify this power recommendation, all tractors that have been rated by the Nebraska Test were evaluated in terms of their plow size and corresponding maximum drawbar horsepower. The figures given are averages for each plow size.

Labor Requirements

The labor requirements for the operation of both the self-propelled and pull-type combines in this study were the same, one man to each unit, since each machine was the tank-type instead of the sacking-type. In the larger machines it is necessary to have an additional man on the pull-type to control the operation of the various units in order to protect the machine from damage, and to get the efficiency obtained by a self-propelled combine where all of the controls are easily accessible to the one operator.

Operating Costs for Combining Oats

The operating costs of farm machines consist of four separate units of cost; namely, machine, labor, fuel and oil costs. Machine cost is made up of a number of items that determine the annual cost of owning it. These costs are depreciation, repairs, interest on investment, insurance, housing, taxes, and lubrication (other than oil changes in crankcase of tractors).

The straight-line method is most commonly used in estimating depreciation of farm machines. The machine cost was determined by using the average and expected useful life in years and hours of machines as set up by Fenton and Barger (34). A machine may reach the end of its useful life by being superceded by a more efficient machine, so the factor of obsolescence necessarily must be taken into account.

Due to the conditions advanced above, even though a machine is not used full capacity or a proportionate number of hours during any particular year, its annual depreciation should be relatively the same. In arriving at the costs in this study the following items were used: the local original cost of machines, annual repair cost of 3 per cent of original cost, interest at 5 per cent of the average investment, taxes, insurance and housing at 2 per cent, and lubrication 1 per cent of the original cost per year. The 1949 local labor rate of 95 cents per hour, gasoline at 18 cents per gallon, and lubricating oil at 25 cents per quart were used in determining the costs. In the case of the pull-type combine and windrowers only the tractor hours used in the operation based on the actual hourly cost per year were charged to harvesting. Since the operating costs for the 1949 season were so close to the three-year costs on the service farms of Iowa State College, the 1949 costs were used

Table 27

Cost of Harvesting Oats per Acre and per Bushel by Various Methods, 1949 Season
215.5 A., 10,957 bu., 50.8 bu/A., Labor $0.95/hr., Gasoline $0.18/gal., Oil $0.25/qt.

Machine	Hours operated	Fuel gal.	Oil qts.	Fuel cost	Oil cost	Labor cost	Depr. cost	Total cost	Acres harv.	Bu. harv.	Cost per acre	Cost per bu.
M.H. s.p. 84" stand. 6 R.	64	2.02 hr. 129	12	23.22	3.00	63.64	329.98	419.85	52.8	2705	$8.06	$0.155
M.H. s.p. 84" windrowed grain 6'	17	1.77 hr. 30	5	5.40	1.25	16.15	87.68	110.48	28.7	1435	3.85	0.077
A. C. 60 combine	100	1.54 hr. 154	15	27.72	3.75	95.00	206.25	332.72	134	6807	2.49	0.049
W. D. tractor	100	1.11 hr. 111	12	19.98	3.00	00.00	39.00	61.98	134	6807	0.46	0.009
A. C. 6' windrower	55	---	--	--	--	52.25	40.20	92.45	160	8128	0.58	0.0114
Ferguson tractor	55	1.15 hr. 63	6	11.34	1.50	00.00	18.76	31.60	160	8128	0.213	0.0039
Rear-mounted windrower	18	---	--	--	--	17.10	34.12	51.22	127	6452	0.403	0.0079
Ford tractor	18	0.83 hr. 15	5	2.70	1.25	00.00	5.22	9.17	127	6452	0.072	0.0014
A. C. 60" combine + W. D. tr.	100	---	--	--	--	95.00	245.25	394.70	134	6807	2.95	0.058
A. C. 6' Wr. + Ferguson tr.	55	---	---	--	--	52.25	58.96	124.05	160	8128	0.793	0.0153
Rear-mounted Wr. + Ford	18	---	--	--	--	17.10	39.34	60.39	127	6452	0.475	0.0094
A. C. 60 c. WD tr. AC 6' Wr.+ Ferg. tr.	--	---	--	--	--	147.25	304.21	518.75	134	6807 7568	3.743	0.0733
AC 60 c. WD tr.; 6' wr.+ Ferg. tr.; rear-mount. Wr. + Ford	--	---	--	--	--	164.35	343.55	579.14	134	6807 8128 6452	4.205	0.0827
M. H. s.p. 84" + AC 6' Wr. + WD tr.	--	---	--	--	--	--	--	--	---	--	4.643	0.0923
M.H. s.p. 84" + AC 6' Wr. + Ferg. tr. + rear-mount.+ Ford tr.	--	---	--	--	--	--	--	--	---	--	5.118	0.1017

Table 28

Costs per Acre for Different Operations in Oat Harvesting for Acreages Ranging from 20 Acres to 400 Acres per Year Based on 1949 Harvesting Costs

Machine	Cost/A 20 A	Cost/A 50 A	Cost/A 100A	Cost/A 150 A	Cost/A 200 A	Cost/A 250 A	Cost/A 300 A	Cost/A 350 A	Cost/A 400 A
M.H. s.p. 84", standing grain	23.35	10.36	6.03	4.59	3.87	3.43	3.14	2.94	2.78
M.H. s.p. 84", wr. grain 6' wn	22.45	9.46	5.13	3.68	2.96	2.53	2.24	2.03	1.88
A. C. 60" combine	11.26	5.07	3.01	2.32	1.98	1.77	1.63	1.53	1.46
W. D. tractor	.46	.46	.46	.46	.46	.46	.46	.46	.46
A. C. 6' windrower	2.34	1.13	0.73	0.60	0.53	0.49	0.46	0.44	0.43
Ferguson tractor	0.213	0.213	0.213	00.213	0.213	0.213	0.213	0.213	0.213
Rear-mounted windrower	1.84	0.82	0.48	0.36	0.31	0.27	0.25	0.23	0.22
Ford tractor	00.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
A. C. 60" comb. + W.D. tr.	11.72	5.53	3.47	2.78	2.44	2.23	2.09	1.99	1.92
A.C. 6' wr. + Ferg. tractor	2.553	1.343	0.943	0.813	0.743	0.703	0.673	0.653	0.643
Rear-mounted wr. + Ford	1.912	0.892	0.552	0.432	0.382	0.342	0.322	0.302	0.292
A.C. 60" comb. W.D. tr. + A.C. 6' wr. + Ferg. tr.	14.273	6.873	4.413	3.593	3.183	2.933	2.763	2.643	2.563
A.C. 60" comb. W.D. tr.; 6' wr. + Ferg. tr.; rear-mount. windrower + Ford	16.185	7.765	4.965	4.025	3.565	3.275	3.085	2.945	2.855
M. H. s.p. 84" + A.C. 6' windrower + Ferg. tr.	25.003	10.803	6.073	4.493	3.703	3.233	2.913	2.683	2.523
M.H. s.p. 84" + A.C. 6' wr. + Ferg. tr. + rear-mounted + Ford opening	26.915	11.695	6.625	4.925	4.085	3.575	3.235	2.985	2.815

Table 29

Comparison of 1949 Harvesting Costs in Dollars per Acre of Harvesting with Self-Propelled and Pull-Type Combines (Pull-Type from Windrow)

Acres per year	M.H. 84" self-propelled: combining standing oats		A. C. 60" pull-type, aux. engine + A.C. 6' windrower	
	Base cost	Base cost less tr. credit	Base cost	Base cost and field op. loss
	dollars	dollars	dollars	dollars
20	23.25	22.89	14.27	14.85
50	10.36	9.90	6.87	7.45
100	6.03	5.57	4.41	4.99
150	4.59	4.13	3.59	4.17
200	3.87	3.41	3.18	3.76
250	3.43	2.97	2.93	3.57
300	3.14	2.68	2.76	3.34
350	2.94	2.48	2.64	3.22
400	2.78	2.32	2.56	3.14

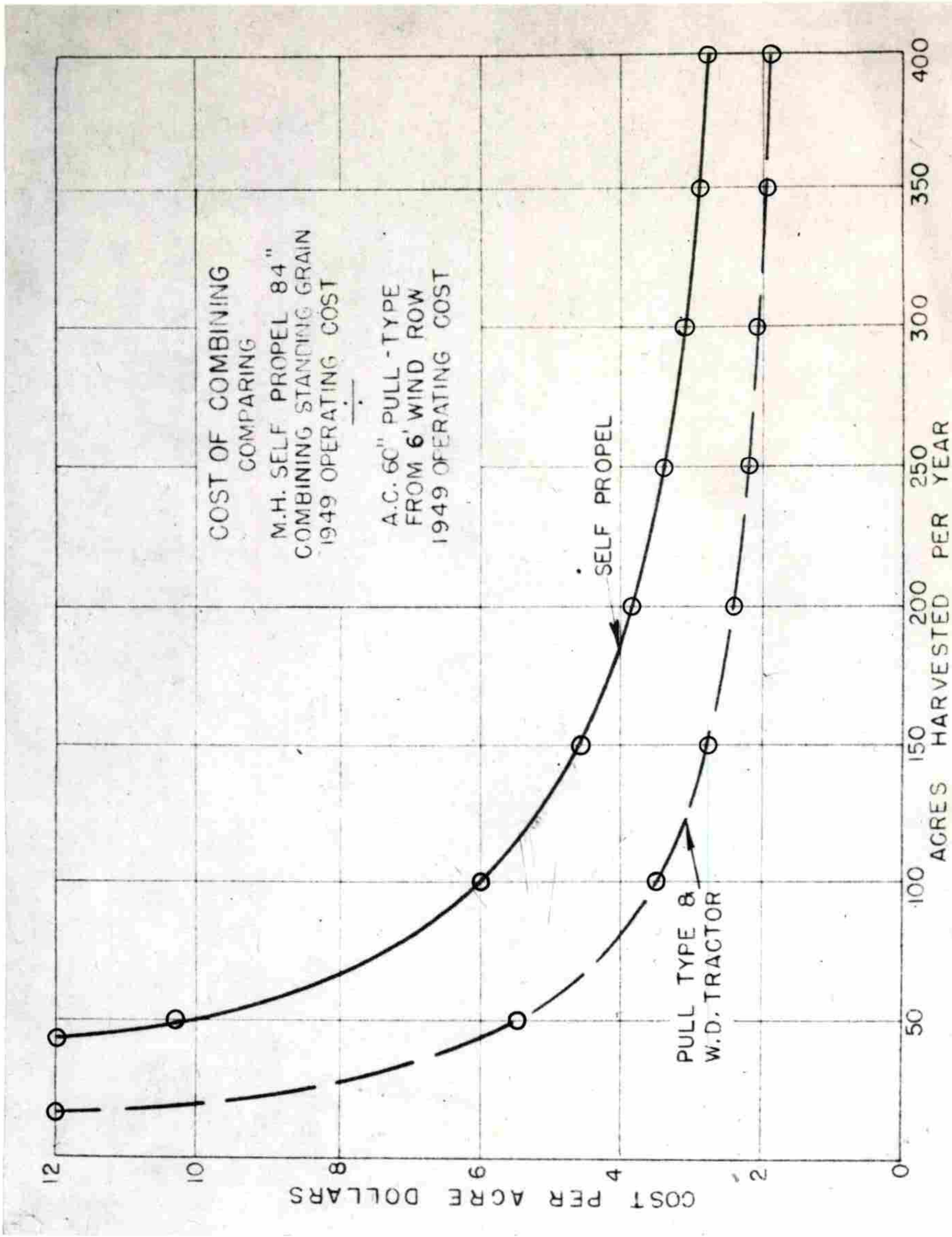

COST OF COMBINING
COMPARING
M.H. SELF PROPEL 84"
COMBINING STANDING GRAIN
1949 OPERATING COST
A.C. 60" PULL-TYPE
FROM 6' WIND ROW
1949 OPERATING COST
SELF PROPEL
PULL TYPE &
W.D. TRACTOR
COST PER ACRE DOLLARS
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
ACRES HARVESTED PER YEAR

Figure 26

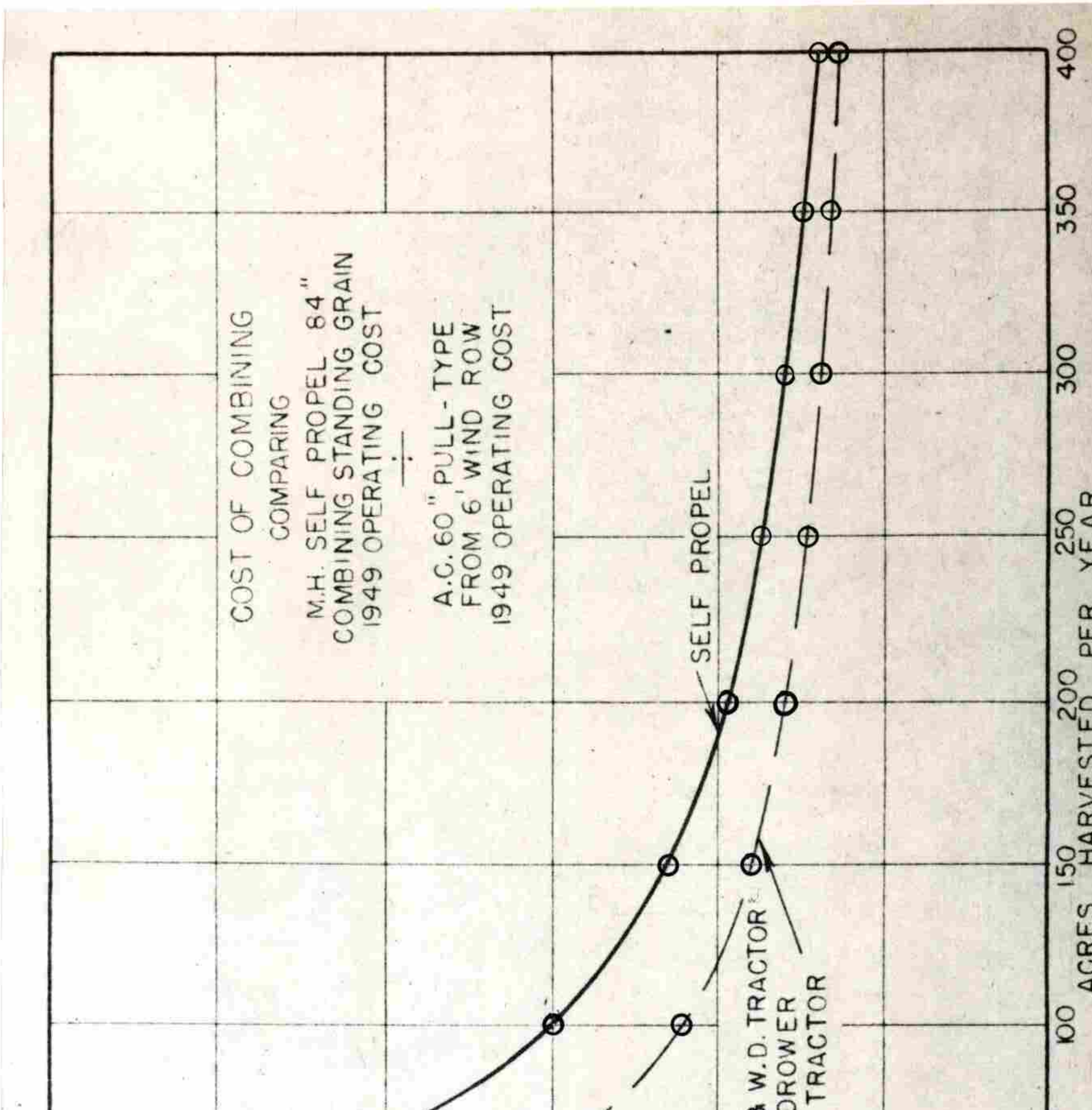
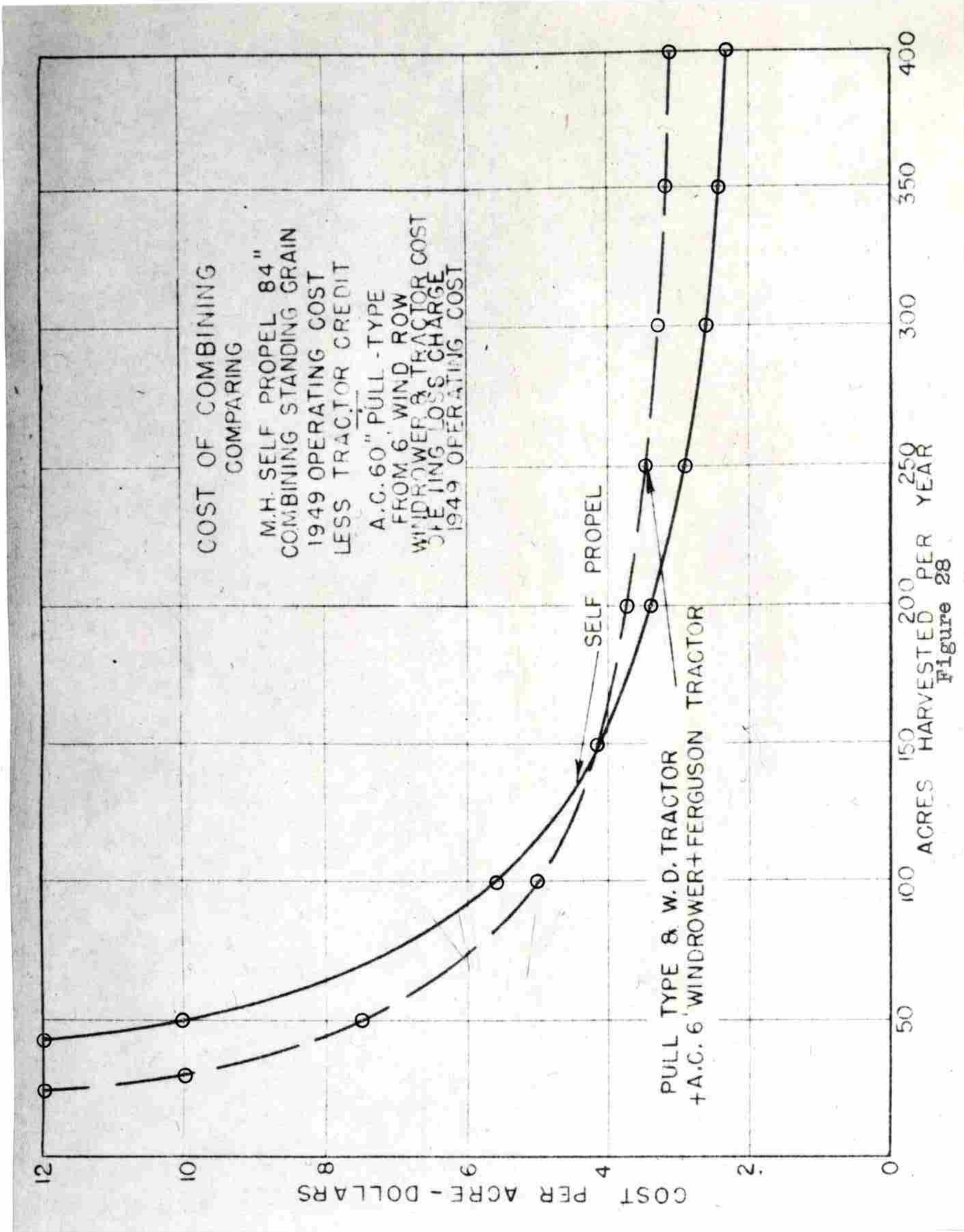
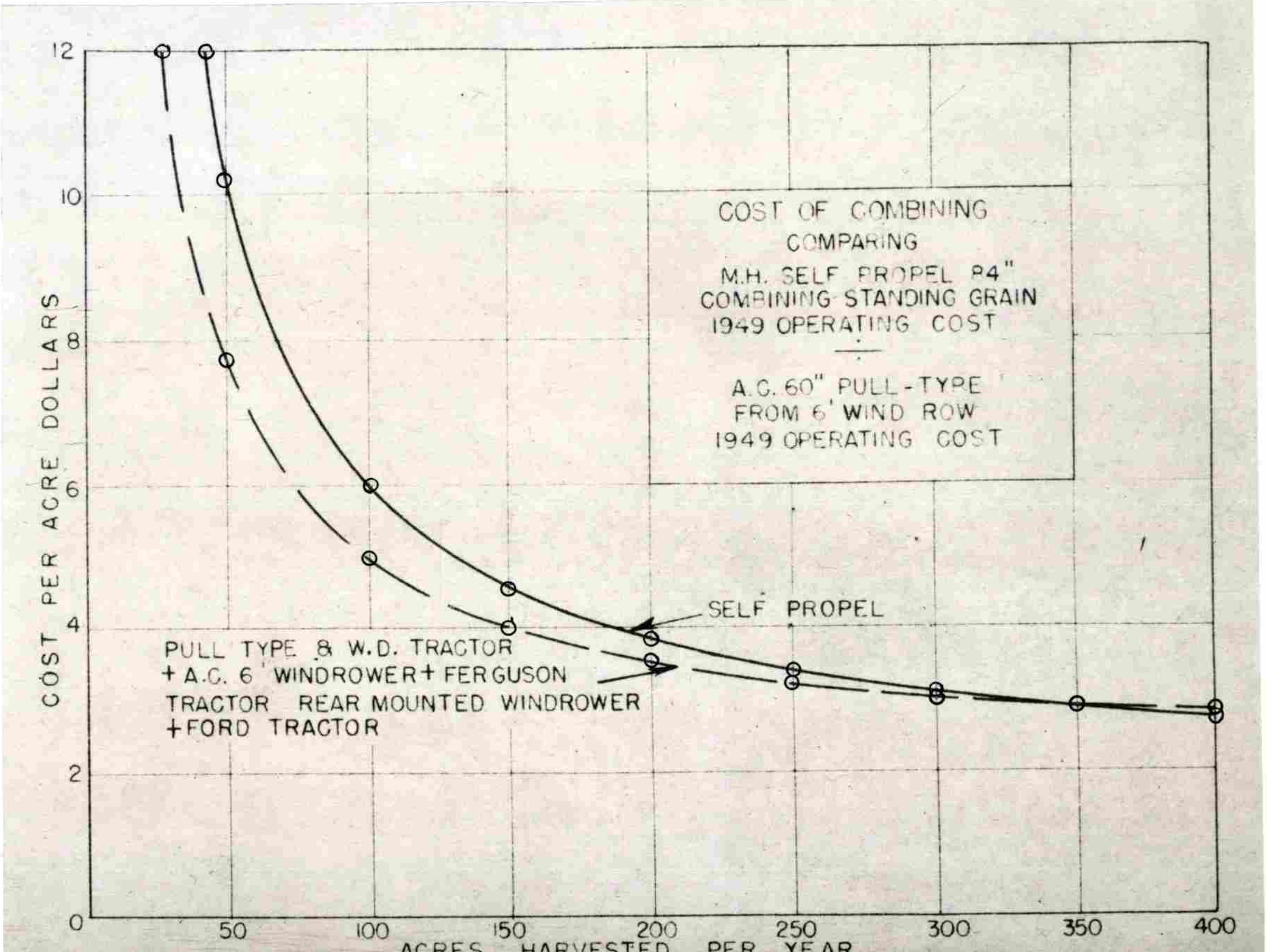

COST OF COMBINING
COMPARING
M.H. SELF PROPEL 84"
COMBINING STANDING GRAIN
1949 OPERATING COST
A.C. 60" PULL-TYPE
FROM 6' WIND ROW
1949 OPERATING COST
SELF PROPEL
PULL TYPE & W.D. TRACTOR
+A.C. 6' WINDROWER
+FERGUSON TRACTOR
COST PER ACRE DOLLARS
ACRES HARVESTED PER YEAR
0
2
4
6
8
10
12
50
100
150
200
250
300
350
400

Figure 27



COST OF COMBINING
COMPARING
M.H. SELF PROPEL 84"
COMBINING STANDING GRAIN
1949 OPERATING COST
LESS TRACTOR CREDIT
A.C. 60" PULL-TYPE
FROM 6' WIND ROW
WINDROWER & TRACTOR COST
SELF PROPEL
PULL TYPE & W. D. TRACTOR
+A.C. 6' WINDROWER + FERGUSON TRACTOR
COST PER ACRE - DOLLARS
ACRES HARVESTED PER YEAR
0
2.
4
6
8
10
12
50
100
150
200
250
300
350
400

Figure 28



COST OF COMBINING
COMPARING
M.H. SELF PROPEL 84"
COMBINING STANDING GRAIN
1949 OPERATING COST
A.C. 60" PULL-TYPE
FROM 6' WIND ROW
1949 OPERATING COST
SELF PROPEL
PULL TYPE & W.D. TRACTOR
+A.C. 6' WINDROWER+FERGUSON
TRACTOR REAR MOUNTED WINDROWER
+FORD TRACTOR
COST PER ACRE DOLLARS
0
2
4
6
8
10
12
50
100
150
200
250
300
350
400
ACRES HARVESTED PER YEAR

Figure 29

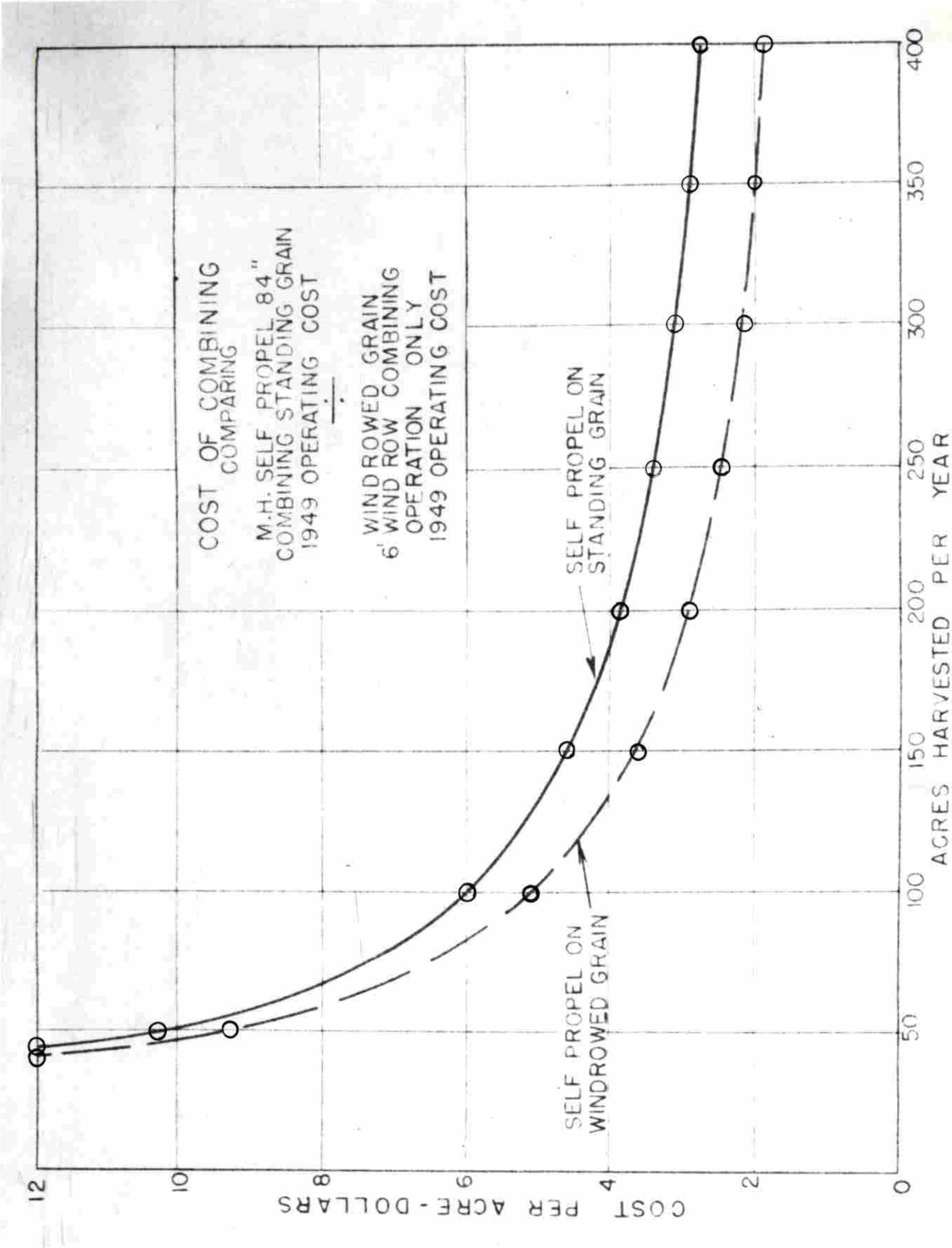

COST OF COMBINING
COMPARING
M.H. SELF PROPEL 84"
COMBINING STANDING GRAIN
1949 OPERATING COST
WINDROWED GRAIN
6' WIND ROW COMBINING
OPERATION ONLY
1949 OPERATING COST
SELF PROPEL ON
STANDING GRAIN
SELF PROPEL ON
WINDROWED GRAIN
COST PER ACRE - DOLLARS
0
2
4
6
8
10
12
ACRES HARVESTED PER YEAR
50
100
150
200
250
300
350
400

Figure 30

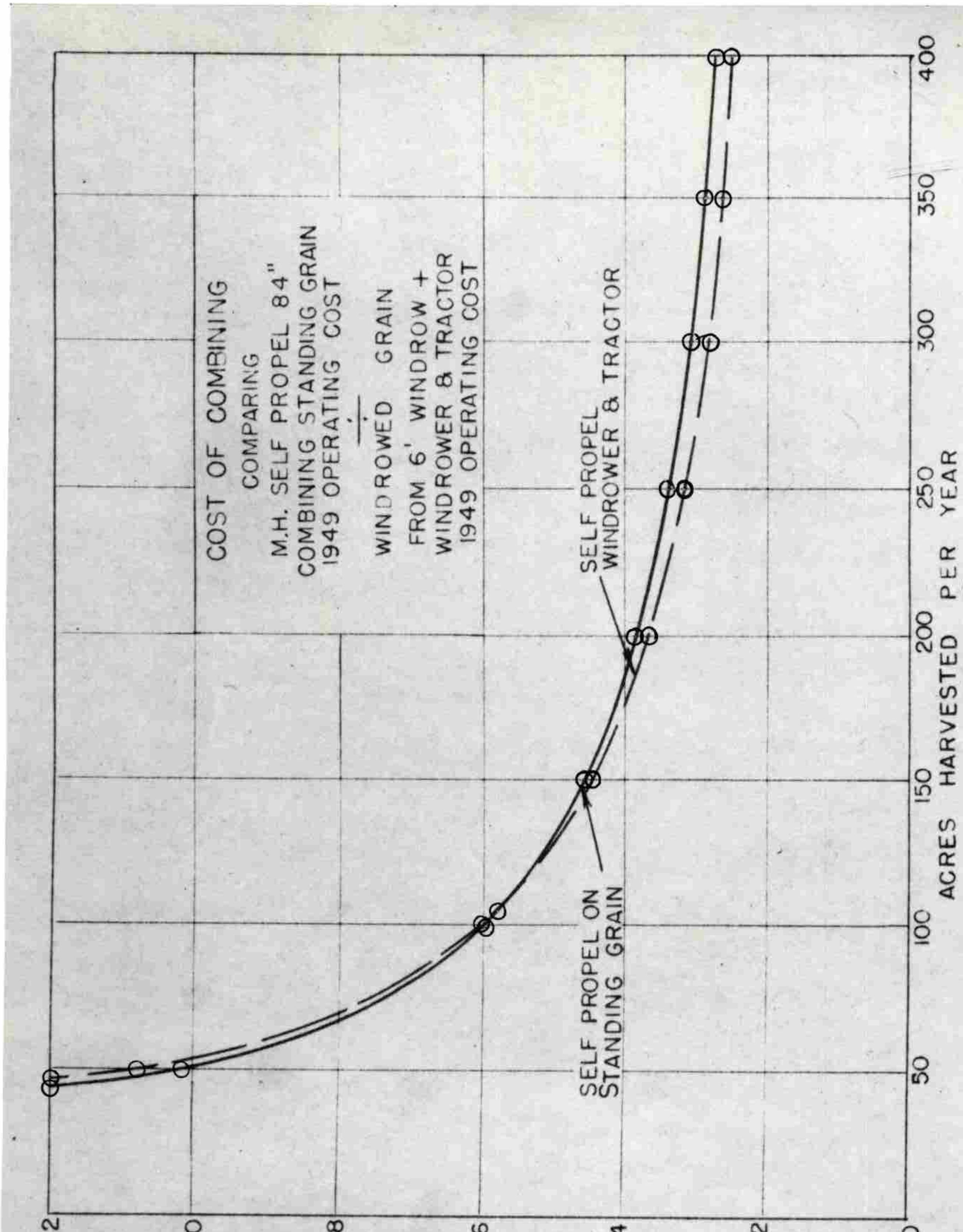

COST OF COMBINING
COMPARING
M.H. SELF PROPEL 84"
COMBINING STANDING GRAIN
1949 OPERATING COST
&
WINDROWED GRAIN
FROM 6' WINDROW +
WINDROWER & TRACTOR
1949 OPERATING COST
SELF PROPEL
WINDROWER & TRACTOR
SELF PROPEL ON
STANDING GRAIN
COST PER ACRE DOLLARS
0
2
4
6
8
10
12
ACRES HARVESTED PER YEAR
50
100
150
200
250
300
350
400

Figure 31

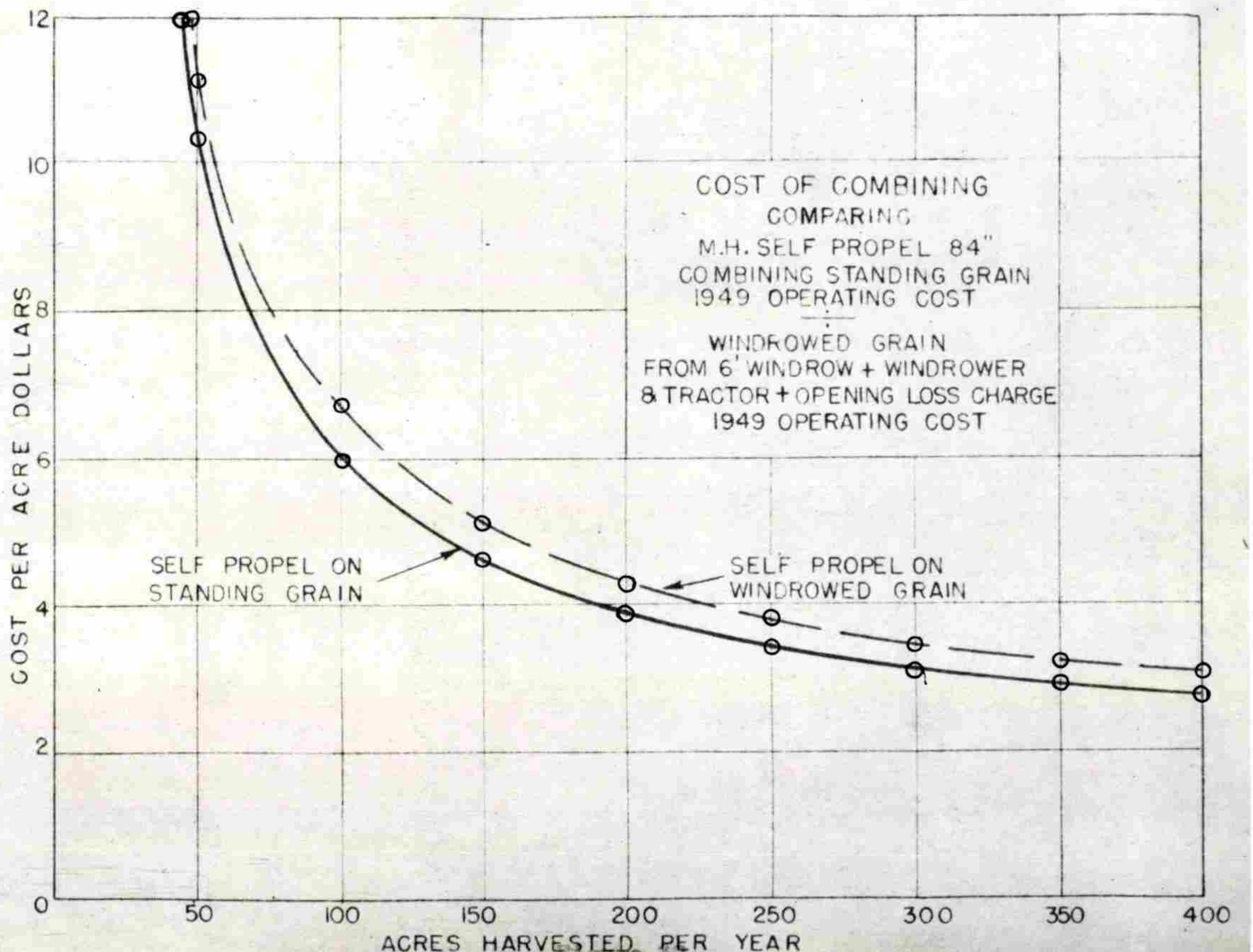

COST OF COMBINING
COMPARING
M.H. SELF PROPEL 84"
COMBINING STANDING GRAIN
1949 OPERATING COST
WINDROWED GRAIN
FROM 6' WINDROW + WINDROWER
& TRACTOR + OPENING LOSS CHARGE
1949 OPERATING COST
SELF PROPEL ON
STANDING GRAIN
SELF PROPEL ON
WINDROWED GRAIN
COST PER ACRE DOLLARS
0
2
4
6
8
10
12
ACRES HARVESTED PER YEAR
50
100
150
200
250
300
350
400

Figure 33

in the calculations to determine the figures in Tables 27 and 28. The average per-acre and per-hour figures for the 1949 season were used to calculate the per-acre costs used in Table 29 and to plot curves, Figures 26, 27, 28, 29, 30, 31 and 32.

The 1949 local market price of oats at 72 cents per bushel was used to figure the opening loss charges against the pull-type combine and the windrowers.

CONCLUSIONS

1. There were no indications from this investigation that mechanical harvesting losses under like conditions were greater for harvesting oats with the self-propelled than with the pull-type combine.

2. There was a significant difference in the losses due to early and late harvesting of standing oats. Early harvesting showed 12.27 per cent loss. Late harvesting showed a loss of 25.215 per cent.

3. The data indicates a wide difference in the losses due to opening fields, for combining, with the tractor mower, pull-type windrower, and push-type rear-mounted windrower. They are listed in the order of causing greatest loss, with 44.61, 41.4 and 32.2, and 11.2 and 3.24 per cent, respectively. (See Table 70, page 67)

4. A decided difference in the skill requirements of the operators was observed in that the self-propelled combine required a much more highly skilled operator, because of the multiple duties involved.

5. The investigation indicates a great saving in the opening cuts by the self-propelled combine. This could

amount to 2,740,000 bushels[a] of oats in Iowa alone.

6. The study indicates a saving in horsepower of approximately 58 per cent per foot of cutter-bar width by the self-propelled combine over the pull-type.

7. On the larger pull-type combines there is need of an extra man to operate the controls and protect the machine in order to get the efficiency that would be had by a self-propelled combine where the controls are easily accessible to the one operator.

8. Where there is a labor shortage, and land conditions are favorable with sufficient acreage of the crop, this study has indicated that the principle of self-propelled transport may mean the difference of saving a crop and losing it, or losing a greater part of it.

9. With the coming of the Uni-Harvestor where the machine will be more versatile, the indications are that this principle will be accepted by the farmers who are operating under favorable conditions.

10. This study has shown (25) that in 1944 only 2.5 per cent of the combines produced were self-propelled but in 1949 it had increased to 13 per cent which is an indication that the principle of self-propelled transport is being accepted by the farmers.

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[a]This figure arrived at by using the 1949 acreage of oats in Iowa and the average production--6,269,000 acres x 2.54% per acre affected x 38 bushels per acre average x 44.61% loss in the opening cut, or 2,740,000 bushels.

SUMMARY

A system of sampling for harvesting losses was set up on a simplified basis, as the methods used in previous investigations were either too simple to get results of much value or required too much field equipment and manpower to be of practical use in the average research program. The system used in this investigation is explained in a previous section of the thesis and is of such a nature that it may be used easily by the farmer for checking his own combining efficiency.

The affected area of fields by opening for combining was determined by checking 230 fields on roads selected randomly around Iowa State College in a radius of 15 miles in which the average acres per field, the number of sides of the field affected, and the per cent per acre were determined. This gives a good basis for determining the losses due to opening fields with mowers, windrowers, and pull-type combines.

Power requirements for combines of the pull-type have been expressed in terms of 1-plow tractor, 2-plow tractor, and other plow sizes. Since power requirements vary with many factors the machinery companies have used a cut-and-try method in the past for settling on the requirements for any particular model. This is also true for the self-propelled

type combines and the auxiliary engines used on the pull-type machines. In this investigation the plow sizes have been reduced to the average horsepower for the plow size. An example of it is that a 2-plow tractor can deliver an average of 21.39 maximum drawbar horsepower.

Labor requirements for each type of combine in this investigation were the actual operators used which was one man per combine.

Costs per acre and per bushel were obtained by using the Straight Line method of depreciation and other standard figures as explained previously, along with the current labor rate, fuel and oil costs, and losses calculated at the local price of oats at the time the study was made in 1948 and 1949.

By spreading these costs per hour over various acreages, the acreage at which they would be equal for both machines was determined.

The pull-type and self-propelled combines were both tested for performance in the field and also over an obstacle course embodying the conditions that combines operate under in Central Iowa and these results put in form A of ratios using the self-propelled combine as 1.

LITERATURE CITED

1. Carrol, Tom. Basic requirements in the design and development of the self-propelled combine. Amer. Soc. Agr. Eng. J. 29:101-103. March 1948.

2. Combined harvesters and threshers. Farm Implement News. 9:18-20. Sept. 1888.

3. Higgins, F. Hal. The combine parade. The Farm Quarterly, Summer 1949. 4:42-47 and 92-104.

4. California Harvest Scene--Dr. Glenn's Farm in Coluse County. Pacific Rural Press. 11:1. Saturday, May 6, 1876.

5. Reynoldson, L. A., Kifer, R. S., Martin, J. H. and Humphries, W. R. The combined harvester-thresher in the Great Plains. U. S. Dept. of Agr. Tech. Bul. 70. 1928.

6. Birkhead, J. W. and Peters, J. H. Two-thirds of small grains combined. Agr. Situation. 31:9-10. June 1947.

7. Everett, C. E., Racine, Wis. Information on the history of the self-propelled combine. (Private communication) July 1948.

8. Farm equipment production by classes 1929 to 1949. Farm Implement News. 71:124-192. July 10, 1950.

9. Zinthero, C. J. Corn harvesting machinery. U. S. Dept. of Agr. Off. Exp. Sta. Bul. 173. 1907.

10. Iowan built corn picker back in 1880's. Wallace's Farmer. 74:442. Apr. 2, 1949.

11. Massey-Harris self-propels the corn harvest. Farm Implement News. 68:44. Jan. 16, 1947.

12. Grimm, Fred T. 4-row corn combine. Successful Farming. 46:198. Oct. 1948.

13. M M Uniharvestor. Farm Implement News. 72:46, 47. Feb. 10, 1951.

14. Some ingenious farm machines. Implement Record. 44:19-23. March 1947.

15. Technocracy again raises its frightful head. Farm Implement News. 69:80. May 20, 1948.

16. Mole, C. A. Our Britisher reports. Farm Implement News. 69:60-62, 141. Sept. 9, 1948.

17. Again the wireless corn planter. Farm Implement News. 70:144. May 5, 1949.

18. Barger, E. L. Engineering management aspects of self-propelled farm machines. Amer. Soc. Agr. Eng. J. 29:106-8. March 1948.

19. Rousseau's "pickup" baler. Farm Implement and Mach. Rev. 73:1182. Apr. 1, 1948.

20. McCay, S. Stuart. The first self-propelled combine. Farm Implement and Mach. Rev. 71:934. March 1, 1946.

21. Brodell, A. P., Birkhead, J. W., and Peters, J. D. Harvesting small grains and utilization of the straw. Farm Implement News. 68:48-50, 90, 92. Sept. 11, 1947. 68:52-53. Sept. 26, 1948. 68:58-59. Oct. 9, 1947. 68:48-49, 80. Oct. 23, 1947. 68:52-53, 122. Nov. 6, 1947. 68: 54-55. Nov. 20, 1947. 68:54-55. Nov. 20, 1947. 68:46-47. Dec. 4, 1947. 68:46-47. Dec. 18, 1947.

22. United States Department of Commerce, Bureau of the Census. Statistical Abstracts 1950. Oats-Acreage, production, and value by states 1938 to 1949. p. 619, table 733.

23. United States Department of Commerce, Bureau of the Census. Statistical Abstracts 1950. Corn-Acreage, production, and value by states 1938-1949. p. 615, table 727.

24. How big can an oyster grow? Farm Implement News. 69:104-110. July 1, 1948.

25. Machinery on farms 1950. Farm Implement News. 71: 83-92. July 10, 1950.

26. Hurst, W. M. The field for the combined harvester-thresher. Amer. Soc. Agr. Eng. J. 16:221. June 1935.

27. Hurst, W. M. and Humphries, W. R. Performance studies of small combines. Amer. Soc. Agr. Eng. J. 17: 249. June 1936.

28. McCuen, G. W. and Silver, E. A. Results of field tests on small combines. Amer. Soc. Agr. Eng. J. 19:207-210. May 1938.

29. Richey, C. B. Determining combine loss on the farm. Ohio Agr. Exp. Sta. Bimonthly Bul. 222:13-136. 1943.

30. Combine losses with the combine harvester. N.I.A.E.J. Agricultural Engineering Record (England). pp. 10-14. Autumn, 1945.

31. Gray, R. B., Hurst, W. M., and Humphries, W. R. Harvesting with combines. U. S. Dept. of Agr. Farmer's Bul. 1761. 1947.

32. Johnson, E. R. and Barger, E. L. Iowa State College Agr. Eng. Dept. Ames, Iowa. Information on methods of harvesting oats in Central Iowa. (Private communication) 1948.

33. Silver, E. A. and Sitterly, J. W. The combined harvester-thresher in Ohio. Ohio Agr. Exp. Sta. Bul. 491. 1931.

34. McCuen, G. W. and Silver, E. A. Combine harvester investigations in Ohio. Ohio Agr. Exp. Sta. Bul. 643. 1943.

35. Bottum, J. C. and Mayer, I. D. The adaptability of the combine to Indiana farms. Purdue Agr. Exp. Sta. Bul. 349. 1931.

36. Jones, Mack M. The combine harvester in Missouri. Missouri Agr. Exp. Sta. Bul. 286. 1930.

37. Barger, E. L. and Fenton, F. C. Cost of using farm machinery. Kansas State Coll. of Agr. and App. Sc. Eng. Exp. Sta. Bul. 45. 1945.

38. Davidson, J. B. Life, service, and the cost of service of farm machines on 400 Iowa farms. Iowa Agr. Exp. Sta. BP 37:282-299. 1942.

39. Barger, E. L. and Heady. E. O. Custom rates for farm machinery. Iowa Farm Science. 2:10-12. June 1948.

40. Downing, D.G.E. Power requirements for power-take-off operated combines. Amer. Soc. Agr. Eng. J. 23:47-50. Feb. 1942.

41. Hobson, E. G. and Wileman, L. H. Mechanical corn pickers in Indiana. Purdue Agr. Exp. Sta. Bul. 362. 1932.

42. Johnston, P. E. and Myers, K. H. Harvesting the corn crop in Illinois. Illinois Agr. Exp. Sta. Bul. 373. 1931.

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APPENDIX

Table 30

Sampling for Combine Losses. Massey-Harris Self-Propelled 84" Combine and A.C. 60" Pull-Type Combines. From Windrow. Opened with 7' tractor mower. Windrowed with A.C. 6' commercial windrower. Swine Breeding Farm. Field 5 Acres. 396' x 550'.
July 11, 19, and 22, 1948

Sample no.	Shatter loss A	Shatter loss Gms	Opening loss A	Opening loss Gms	Windrower loss A	Windrower loss Gms	Threshing loss A	Threshing loss Gms	Separating loss A	Separating loss Gms	Pickup loss A	Pickup loss Gms	Net yield A	Net yield Lbs
1	.0001	0.8	.0002	142.3	.000	15.2	.000	4.6	.000	26.8	.000	11.8	No yield	
2	Acre	0.2	Acre	147.8	276	9.8	593	1.1	593	7.8	277	9.9	samples	
3	"	0.2	"	26.8	Acre	3.9	Acre	3.9	Acre	3.9	Acre	9.6	taken from	
4	"	0.1	"	42.8	"	4.8	"	9.7	"	8.5	"	10.4	this	
5	"	0.2	"	35.7	"	7.4	"	1.9	"	1.9	"	20.2	machine	
6	"	0.1	"	44.6	"	16.6	Above samples, Massey-Harris S.P.							
7	"	0.1	"	62.0	"	8.8	84" Combine							
8	"	0.0	"	106.6	"	5.9	Below, A.C. 60" Pull-type Combine							
9	"	0.5	"	74.5	"	4.6	.000		.000		.000		.000	3.750
10	"	0.3	"	126.1	"	3.5	593	1.2	593	13.7	277	14.4	165	2.500
11	"	0.1	"	112.3	"	6.5	Acre	0.2	Acre	6.5	Acre	20.4	Acre	2.940
12	"	0.7	"	128.9	"	3.4	"	0.6	"	4.2	"	9.6	"	2.500
13	"	0.9	"	63.0	"	---	"	1.1	"	1.8	"	10.8	"	1.370
14	"	0.2	"	76.8	"	---	"	1.6	"	8.2	"	28.8		
15	"	0.2	"	146.1	"	---	"	0.1	"	0.8	"	19.2		
16	"	0.5	"	48.3	"	---	"	0.1	"	35.4	"	2.4		
17	"	---	"	42.0	---	---	"	0.1	"	5.0	"	12.0		
18	---	---	"	19.0	---	---	"	1.9	"	12.4	"	3.6		
19	---	---	"	73.0	---	---	"	0.4	"	4.3	"	27.6		
20	---	---	"	82.0	---	---	---	---	---	---	---	---		

Table 31

Sampling for Harvesting Losses. Massey-Harris 84" Self-Propelled Combine. From Windrow
Field opened and windrowed with A. C. 6' pull-type windrower. Dairy Farm, 18.1 Acres.
July 15, 22, 23, 1949

Sample no.	Shatter loss		Windrower loss		Opening loss		Threshing loss		Separation loss		Pickup loss		Yield net	
	A	Gms	A	Gms	A	Gms	A	Gms	A	Gms	A	Gms	A	Lbs
1	.0001	.1	.0002	11.6	.0002	34.0	.00064	.5	.00064	3.7	.0002	32.2	.00276	3.08
2	"	1.7	"	27.9	"	35.4	"	.5	"	12.2	"	64.4	"	2.36
3	"	.7	"	57.5	"	58.8	"	.3	"	4.6	"	120.4	"	2.39
4	"	.2	"	7.9	"	58.8	"	.7	"	29.4	"	32.2	"	3.04
5	"	.1	"	12.1	"	135.4	"	2.1	"	9.8	"	31.4	"	2.73
6	"	1.1	"	8.5	"	123.9	"	.6	"	10.6	"	34.0	"	4.02
7	"	1.5	"	10.9	"	155.5	"	.6	"	3.8	"	45.4	"	3.62
8	"	.5	"	20.0	"	78.6	"	2.7	"	19.7	"	46.1	"	4.11
9	"	1.2	"	26.3	"	123.3	"	1.1	"	8.2	"	65.3	"	3.17
10	"	.3	"	13.1	"	42.5	"	.6	"	2.5	"	115.8	"	4.02

Table 32

Sampling for Combining Losses. Massey-Harris Self-Propelled 84" Combine. From Windrow Field opened and windrowed with 8' rear-mounted windrower. Atomic Energy Farm. Field 11.3 Acres. July 27 and August 3, 1948.

Sample no.	Shatter loss A	Shatter loss Gms	Opening loss A	Opening loss Gms	Windrower loss A	Windrower loss Gms	Threshing loss A	Threshing loss Gms	Separating loss A	Separating loss Gms	Pickup loss A	Pickup loss Gms	Net Yield A	Net Yield Gms
1	.0001	1.3	.0075	--	.0002	13.4	.00079	0.3	.00079	10.2	.0001	10.0	.00184	0.585
2	Acre		Acre		Acre		Acre		Acre		Acre		Acre	
2	"	6.3	"	--	"	31.0	"	0.4	"	17.5	"	19.3	"	3.585
3	"	2.5	"	51.3	"	22.3	"	0.0	"	10.7	"	12.3	"	0.960
4	"	2.3	"	--	"	14.0	"	0.2	"	15.2	"	27.1	"	2.085
5	"	4.8	"	57.8	"	15.1	"	0.5	"	16.8	"	14.2	"	3.460
6	"	2.0	"	--	"	17.7	"	0.6	"	15.5	"	15.5	"	1.335
7	"	4.1	"	--	"	10.4	"	1.5	"	4.3	"	4.1	"	0.960
8	"	2.5	"	--	"	19.0	"	0.2	"	13.6	"	13.5	"	3.085
9	"	2.3	"	76.1	"	13.5	"	0.6	"	12.3	"	13.8	"	1.210
10	"	3.1	"	--	"	9.7	"	1.2	"	17.5	"	11.3	"	3.710

Table 33

Sampling for Combining Losses. Massey-Harris Self-Propelled 84" Combine. Standing Grain. Animal Husbandry Farm. Field 21 Acres. Str. Ran. Sampled.* July 30, 31, and August 2, 1948

Sample no.	Shatter loss A	Shatter loss Gms	Cutter-bar & shatter A	Cutter-bar & shatter Gms	Threshing loss A	Threshing loss Gms	Separating loss A	Separating loss Gms	Net yield A	Net yield Gms
1	.0001 Acre	24.9	.0001 Acre	22.8	.00069 Acre	0.0	.00069 Acre	12.3	.000161 Acre	1.322
2	"	7.2	"	14.5	"	0.0	"	7.0		0.447
3	"	18.4	"	19.6	"	0.0	"	17.4	"	3.509
4	"	11.9	"	27.7	"	0.0	"	15.2	"	3.197
5	"	5.0	"	27.8	"	1.8	"	65.0	"	2.134
6	"	1.1	"	91.0	"	0.0	"	11.6	"	2.634
7	"	21.1	"	3.4	"	0.0	"	8.5	"	1.884
8	"	4.0	"	44.0	"	0.0	"	9.6	"	0.822
9	"	1.0	"	9.9	"	0.0	"	9.6	"	0.697
10	"	4.0	"	37.9	"	0.0	"	11.4	"	3.384

*This field was divided into five equal-size strata and two samples taken randomly from each strata.

Table 34

Sampling for Harvesting Losses. Massey-Harris 84" Self-Propelled Combine. Standing Grain. Animal Husbandry Farm, 31.2 Acres. July 13, 14, 15, 1949.

Sample no.	Shatter loss		Threshing loss		Separating loss		Cutter-bar loss		Yield net	
	A	Gms	A	Gms	A	Gms	A	Gms	A	Lbs
1	.0001	.5	.00064	0.0	.00064	1.9	.0001	2.6	7'x20' .00322	8.35
2	"	1.2	"	1.5	"	8.5	"	6.5	"	4.94
3	"	1.3	"	.1	"	9.5	"	6.0	"	4.22
4	"	.0	"	.1	"	13.6	"	4.3	"	2.63
5	"	.1	"	.6	"	39.0	"	16.1	"	5.37
6	"	.1	"	.1	"	24.1	"	6.9	"	5.68
7	"	.6	"	.3	"	12.4	"	13.9	"	4.24
8	"	.3	"	.0	"	182.5	"	3.9	"	8.32
9	"	1.3	"	.1	"	12.8	"	4.3	"	9.98
10	"	.4	"	.5	"	7.2	"	14.8	"	7.92

Table 35

Sampling for Harvesting Losses. Allis-Chalmers 60" Pull-Type Combine. From Windrow. Field opened and windrowed with Allis-Chalmers 6' pull-type windrower. South 450 Farm, 11 Acres. July 7, 9, 11, 12, 1949.

Sample	Shatter loss		Windrower loss		Opening loss		Threshing loss		Separation loss		Pickup loss		Yield net	
no.	A	Gms	A	Gms	A	Gms	A	Gms	A	Gms	A	Gms	A	Gms
1	.0001	.2	.0002	1.0	.0002	37.8	.00055	.1	.00055	1.3	.0002	1.2	.00276	1.04
2	"	.1	"	7.3	"	74.5	"	.1	"	1.2	"	1.3	"	4.45
3	"	1.5	"	6.5	"	92.1	"	.3	"	4.7	"	2.7	"	5.12
4	"	.1	"	3.0	"	86.5	"	2.1	"	9.3	"	21.1	"	4.02
5	"	.2	"	6.1	"	22.6	"	.3	"	3.4	"	4.1	"	4.26
6	"	.02	"	2.2	"	42.6	"	.1	"	2.8	"	2.6	"	2.72
7	"	.8	"	1.8	"	93.6	"	1.8	"	14.3	"	48.1	"	3.31
8	"	.0	"	1.2	"	99.9	"	.9	"	7.4	"	10.1	"	4.64
9	"	.2	"	5.3	"	92.6	"	.2	"	4.9	"	1.2	"	4.95
10	"	1.2	"	10.1	"	66.9	"	1.2	"	7.8	"	14.1	"	6.32

Table 36

Sampling for Harvesting Losses. Allis-Chalmers 60" Pull-Type Combine. Opening with 8' Rear-mounted Windrower. Single windrow. Allis-Chalmers 6' Windrower. Swine Farm, Field 2. 7.31 Acres. July 11, 13, 1949.

Sample	Shatter loss		Windrower loss		Opening loss		Threshing loss		Separation loss		Pickup loss		Yield net	
no.	A	Gms	A	Gms	A	Gms	A	Gms	A	Gms	A	Gms	A	Gms
													6'x20'	
1	.0001	1.1	.0002	5.1	.0002	9.2	.00055	7.1	.00055	15.7	.0002	26.3	.00276	5.05
2	"	.5	"	2.3	"	18.7	"	6.0	"	53.1	"	86.8	"	5.22
3	"	1.4	"	5.6	"	9.0	"	14.3	"	3.2	"	4.1	"	5.67
4	"	3.5	"	8.7	"	21.2	"	.1	"	2.5	"	4.9	"	2.40
5	"	2.1	"	5.9	"	27.7	"	10.5	"	47.1	"	67.6	"	5.33
6	"	.7	"	2.8	"	12.3	"	1.7	"	105.8	"	133.0	"	1.16
7	"	.1	"	1.4	"	6.3	"	.5	"	.8	"	1.6	"	3.90
8	"	1.5	"	6.7	"	2.3	"	.5	"	10.6	"	16.6	"	6.05
9	"	2.1	"	3.9	"	5.2	"	1.7	"	29.7	"	43.8	"	7.07
10	"	.1	"	2.2	"	2.5	"	3.3	"	1.1	"	1.8	"	8.07

Table 37

Sampling for Harvesting Losses. Allis-Chalmers 60" Pull-Type Combine. Field opened three sides with rear-mounted windrower. Windrowed with A.C. 6' Windrower. East 450 Farm, 32.1 Acres. July 8, 18, 19, 20, 21, 1949.

Sample no.	Shatter loss A	Shatter loss Gms	Windrower loss A	Windrower loss Gms	Opening loss A	Opening loss Gms	Threshing loss A	Threshing loss Gms	Separation loss A	Separation loss Gms	Pickup loss A	Pickup loss Gms	Yield net A	Yield net Gms
													6'x20'	
1	.0001	.3	.0002	6.2	.0002	49.2	.00055	.1	.00055	5.6	.0002	19.5	.00276	7.67
2	"	.0	"	8.3	"	40.6	"	.1	"	1.4	"	33.6	"	6.57
3	"	.1	"	11.0	"	36.2	"	5.5	"	9.4	"	32.2	"	3.42
4	"	.2	"	7.6	"	35.4	"	.0	"	62.5	"	24.6	"	4.06
5	"	.2	"	9.2	"	8.3	"	.0	"	10.5	"	28.1	"	4.11
6	"	1.2	"	5.2	"	59.1	"	.0	"	1.8	"	15.6	"	5.47
7	"	2.0	"	5.1	"	50.7	"	.4	"	4.9	"	17.6	"	5.30
8	"	.02	"	3.7	"	4.8	"	.7	"	13.0	"	8.8	"	3.77
9	"	.02	"	2.7	"	6.2	"	.2	"	4.3	"	6.4	"	7.88
10	"	.1	"	5.5	"	4.0	"	.7	"	13.1	"	5.6	"	6.52

Table 38

Oat Weight Samples
100 grains/sample

Sample no.	Weight, gms
1	2.0
2	2.1
3	2.4
4	2.1
5	2.2
6	1.9
7	2.0
8	2.1
9	2.2
10	2.1

2.11/100 grains

1 grain = 0.0211 gms

1 sq ft = .0000229 A

.0000229 x 454 = .0103966 Factor or

2.024 lb/Acre

1 grain/sq ft = 2.024 lb/Acre

16 grain/sq ft =32.38 lb/Acre or 1 bu/Acre

Table 39

Operating Time. Allis-Chalmers 60" Pull-type Combine.

Day	On job hours	On job min	Lost hours	Lost min	Operated hours	Operated min
7- 9-49	3	35	1	07	2	28
7-11-49	10	00	2	39	7	21
7-12-49	10	35	2	30	8	05
7-13-49	10	54	2	35	8	19
7-14-49	9	58	2	02	7	56
7-15-49	10	30	1	55	8	35
7-16-49	10	12	1	38	8	34
7-18-49	4	22	1	36	2	56
7-19-49	9	15	2	29	6	46
7-20-49	4	14	1	03	3	11
7-21-49	9	17	2	10	7	07
7-22-49	10	08	1	55	8	13
7-23-49	4	27	1	55	2	32
13 days	107	27	25	34	81	53
Lunch periods	7	42				
	99	45				

$$100 \times \frac{81.883}{99.75} = 82.09 \text{ per cent}$$

$$100 - 82.09 = 17.91 \text{ per cent lost time}$$

$$81.883 - 5 = 76.883$$

$$\frac{76.883}{11} = 6.99 \text{ hrs operated per day}$$

Table 40

Operation Speed Test. Allis-Chalmers 60" Pull-type Combine.
Operating on windrowed grain. 50.4 bu/acre.

Test no.	Distance traveled feet	Time min	Time sec
1	336	1	2
2	336	1	3
3	324	1	0
4	324	1	1
5	312	0	56
6	312	0	55
7	290	0	49
8	290	0	50
9	278	0	43
10	278	0	42
	2750	9.016	

350.13 ft/min

3.99 mi/hr

2.9 A/hr = .58 A/hr/ft cutter-bar width

149 bu/hr = 29.8 bu/hr/ft cutter-bar width

Test no.	Unloading time min	Unloading time sec	Turning time sec
1	1	36	18.2
2	1	32.5	18.6
3	1	42	19.1
4	1	48	18.1
5	1	30.5	18.7
6	1	40.2	21.3
7	1	47	17.7
8	1	41	18.2
9	1	58	20.3
10	1	33	18.4
Average	1.68 min		18.86

Table 41

Operation Speed Test. Massy-Harris 84" Self-propelled Combine.
86.8 bu/acre Av. 700' distance

Test no.	Time min	Time sec	Turning time sec
1	2	50	13.5
2	2	56	8.5
3	2	58	8.2
4	2	51.4	10.0
5	2	55.5	8.2
6	2	46.3	6.3
7	2	36.5	19.0
8	2	55.5	6.2
9	2	40	8.1
10	2	46	6.4
Average	2.8253		9.44

247.8 ft/min
2.82 miles/hr
2.39 acre/hr
207 bu/hr
.341 acre/hr/ft of cutter-bar width
29.6 bu/acre/ft cutter-bar width

Test no.	Unloading time min	Unloading time sec
1	3	5.0
2	2	54.0
3	3	3.5
4	3	6.2
5	2	56.0
6	3	1.5
7	3	6.2
8	2	52.0
9	3	4.6
10	3	2.8
Average	3.02 min	

Table 42

Portability Test, August 8, 1949
Allis-Chalmers 60" Combine plus W. D. Tractor

Test A

Servicing and Starting

Check no.	Time, min
1	11.81

Test B

Travel on Pavement .8 mi

Check no.	Speed mph
1	10.12
2	11.62
Av.	10.87

Test C

Travel down hill

Check no.	Speed mph
1	12.55
2	11.55
3	7.35
Av.	10.48

Test D

Travel up hill

Check no.	Speed mph
1	8.05
2	8.85
3	7.09
Av.	7.997

Test E

Level travel

Check no.	Speed mph
1	10.25
2	9.76
3	9.07
4	8.82
5	12.23
6	10.70
Av.	10.27

Test F

Level travel 1 mi

Check no.	Speed mph
1	11.55

Test G

Time to enter 12' gate

Check no.	Time, min
1	1.485
2	1.818
Av.	1.651

Test H

Time to leave 12' gate

Check no.	Time, min
1	.994
2	1.557
Av.	1.275

(Continued on next page)

Table 42 (Cont'd)

Test I

Time to enter 24' gate

Check no.	Time, min
1	.1

Test J

Time to leave 24' gate

Check no.	Time, min
1	.117

Test K

Travel in lane

Check no.	Speed mph
1	10.80
2	8.72
Av.	9.76

Test L

Storing time

Check no.	Time, min
1	3.58

Test M

Total elapsed time over course

Check no.	Time, hours
1	1.292

Table 43

Portability Test, August 9, 1949
Massey-Harris 84" Self-Propelled Combine

Test A

Servicing and starting

Check no.	Time, min
1	15.6

Test B

Travel on pavement .8 mi

Check no.	Speed mph
1	5.61
2	5.91
Av.	5.75

Test C

Travel down hill

Check no.	Speed mph
1	5.38
2	5.97
3	7.41
4	6.00
Av.	6.19

Test D

Travel up hill

Check no.	Speed mph
1	4.02
2	5.28
3	5.12
4	6.52
Av.	5.23

Test E

Level travel

Check no.	Speed mph
1	4.82
2	5.39
3	6.33
4	5.08
Av.	5.40

Test F

Level travel 1 mi

Check no.	Speed mph
1	6.48

Test G

Time to enter 12' gate

Check no.	Time, min
1	.0163
2	.09
Av.	.0531

Test H

Time to leave 12' gate

Check no.	Time, min
1	.107
2	.042
Av.	.074

(Continued on next page)

Table 43 (Cont'd)

Test I

Time to enter 24' gate

Check no.	Time, min
1	.0417

Test J

Time to leave 24' gate

Check no.	Time, min
1	.057

Test K

Travel in lane

Check no.	Speed mph
1	6.28
2	7.07
Av.	6.67

Test L

Storing time

Check no.	Time, min
1	.69

Test M

Total elapsed time over course

Check no.	Time, hours
1	1.80

Table 44

Time Study on Allis-Chalmers 60" Pull-Type and Massey-Harris Self-Propelled Combines over Transportation Course to Determine Portability Factors
August 8 and 9, 1949

Item	Allis-Chalmers 60" pull-type Check number						Massey-Harris Self-Propelled 84" Check number					
	1	2	3	4	5	6	1	2	3	4	5	6
	M : S	M : S	M : S	M : S	M : S	M : S	M : S	M : S	M : S	M : S	M : S	M : S
Servicing and starting	11 49.0						15 36.0					
Travel on pavement .8 mi	4 45.0	4 8.2					8 56.1	8 14.0				
Travel downhill	350' 0 19.4	540' 0 31.9	700' 1 6.5				350' 0 44.3	540' 1 1.7	700' 1 4.4	800' 1 31.0		
Travel uphill	350' 0 29.7	540' 0 41.5	700' 1 7.5				350' 0 51.0	540' 1 9.7	700' 1 13.3	800' 1 46.3		
Level travel	300' 0 16.7	600' 0 41.6	800' 0 55.9	300' 0 19.1	600' 0 46.5	800' 0 53.3	600' 1 25.0	750' 1 34.7	1000' 1 47.8	720' 1 36.6		
Level travel 1 mi	5 11.6						9 16.7					
Enter 12' gate from lane	1 29.0	1 49.2					0 9.8	0 5.4				
Leave 12' gate to lane	0 59.6	1 33.4					0 6.4	0 2.5				
Enter double gate from lane	0 6.0						0 2.5					
Leave double gate to lane	0 7.0						0 3.4					
Travel in lane	800' 0 50.1	1120' 1 27.5					800' 1 26.9	800' 1 17.3				
Storing machine	3 28.0						0 41.0					
Total elapsed time	1 hr. 17.5 M						1 hr 48 M					

Table 45

Power Requirements of Self-Propelled Combines[a]

Size of combine (width of cut, ft)	Weight	Horsepower of engine @ rpm	Horsepower/ft of cut width
7	5,200	30 @ 1500	4.3
8.5	5,850	52 @ 2000	6.12
10	5,600	52 @ 1600	5.2
10	--	28.5 @ 1500	2.85
12	7,000	52 @ 2000	4.33
12	8,500	52 @ 2000	4.33
12	6,750	62 @ 2050	5.17
12	7,217	48 @ 1800	4.00
12	--	42 @ 1200	3.5
12	6,750	52 @ 2000	4.33
12-2/3	7,273	45 @ 1763	3.56
13	8,100	35 @ 1900	2.69
13.5	--	42 @ 1200	3.12
14	7,700	35 @ 1900	2.50
15	7,200	58 @ 2000	3.87
Av. 11.68		45.7	3.92

[a]Information in this table was taken from Red Tractor Book, 1950-51, Combines, Self-Propelled, Implement and Tractor, pages 376, 377, Tractor, Farm and Industrial Engines, pages 222-248. These figures are a summary of the information of the 15 models manufactured by the seven major implement companies building self-propelled combines.

Table 46

Power Requirements of Pull-Type Combines[a]

Width, size	Weight	Plow size & HP of tractor[b]		Horsepower of aux. engine	Total HP	HP/ft width
3.5	3,060	1	14.35	13 @ 1600	27.35	7.87
4.5	2,702	2	21.39	6 @ 2500	27.39	6.08
5	3,360	2	21.39	24.5 @ 1600	45.89	9.19
5	-----	1-2	15.63	P.T.O.	15.63	3.13
5	4,890	2	21.39	43 @ 2600	64.39	12.88
5	2,600	1-2	15.63	21.5 @ 2000	37.13	7.42
5.5	-----	2-3	22.38	14.34@ 1850	36.72	6.66
5.5	3,500	2	21.39	37.00@ 2400	51.39	9.34
6	3,577	2-3	22.38	21.50@ 2000	43.88	7.3
6	3,218	2	21.39	21.50@ 2000	42.89	7.14
6	3,584	2	21.39	15.00@ 2000	36.39	6.06
6	-----	2	21.39	25.00@ 2400	46.39	7.72
6.5	4,045	2	21.39	24.50@ 1790	45.89	7.05
7	-----	2	21.39	25.00 @ 2400	46.39	6.62
7	4,650	2	21.39	33.80 @ 1500	55.19	7.88

[a]Information in this table was taken from Red Tractor Book, 1950-51, by Implement and Tractor, pages 378 and 379, Tractor, Farm and Industrial Engines, pages 222-248.

[b]The information concerning plow size of tractor and the average horsepower shown was taken from Illustrated Tractor Specifications 1950 Tractor Field Book, by Farm Implement New.

(Continued on next page)

Table 46 (Cont'd)

Width, size	Weight	Plow size & HP of tractor		Horsepower of aux. engine	Total HP	HP/ft width
8	5,350	2	21.39	43.00 @ 2600	64.39	8.05
9	4,271	2	21.39	24.00 @ 1425	45.39	5.04
9	5,635	2	21.39	38.75 @ 2000	93.66	10.42
12	5,207	3-4	38.45	24.00 @ 1425	62.45	5.19
12	5,945	3	33.52	69.00 @ 3200	102.52	8.55
12	5,735	2	21.39	38.75 @ 2000	93.66	7.80
12	6,700	2	21.39	15.00 @ 2000	36.39	3.03
12	4,990	2	21.39	33.80 @ 1500	55.19	4.58
12	5,875	2	21.39	32.00 @ 1440	51.39	4.27
12	5,975	2-3	22.38	38.00 @ 1450	60.38	5.03
16	11,924	4-5	47.81	38.00 @ 1590	85.81	5.37
20	11,471	4-5	47.81	58.30 @ 3200	106.11	5.32
20	11,100	4-5	47.81	55.00 @ 1275	102.81	5.13
20	15,000	4	44.81	58.30 @ 3200	103.11	5.16
Av. 9.34					58.1	6.23

Table 47

Opening Loss Area and Per Cent per Acre Loss due to Opening Oat Fields with Pull-Type Combines, Tractor Mower or Commercial Windrowers

No.	Dimensions, ft	Acreage	Sides affected	Area aff. acre	Per cent
1	414 x 2500	23.7	2s-1e	0.864	3.64
2	1320 x 1320	40	4 sides	.840	2.10
3	396 x 550	5	4 sides	.295	5.90
4	1320 x 1320	40	4 sides	.840	2.10
5	400 x 2182	20	4 sides	.820	4.08
6	250 x 2640	15	2 sides	.465	3.10
7	400 x 1320	12	1s-1e	.272	2.26
8	396 x 550	5	4 sides	.295	5.90
9	500 x 1320	15	4 sides	.603	4.01
10	1145 x 1145	30	4 sides	.728	2.42
11	300 x 2180	15	4 sides	.787	5.24
12	992 x 1320	30	4 sides	.728	2.42
13	1320 x 1320	40	4 sides	.840	2.10
14	497 x 2640	30	4 sides	1.000	3.34
15	1488 x 2640	90	4 sides	1.315	1.46
16	992 x 1320	30	4 sides	.728	2.42
17	500 x 1744	20	4 sides	.713	3.56
18	1320 x 1980	60	4 sides	1.035	1.73
19	1320 x 1650	50	4 sides	.942	1.88
20	1320 x 1980	60	4 sides	1.035	1.73
21	1320 x 1650	50	4 sides	.942	1.88
22	935 x 935	20	4 sides	.590	2.94
23	1320 x 1320	40	4 sides	.840	2.10
24	1320 x 2640	80	4 sides	1.260	1.575
25	1320 x 1320	40	4 sides	.840	2.10
26	468 x 468	5	4 sides	.291	5.83
27	992 x 1320	30	4 sides	.728	2.42
28	330 x 1320	10	4 sides	.260	2.60
29	396 x 550	5	4 sides	.131	2.63
30	1320 x 1320	40	4 sides	.840	2.10
31	1320 x 2640	80	4 sides	.840	1.575
32	1320 x 1980	60	2s-1e	.734	1.230
33	468 x 468	5	4 sides	.291	5.83
34	330 x 2640	20	1s-2e	.523	2.63
35	330 x 662	5	4 sides	.310	6.20

(Continued on next page)

Table 47 (Cont'd)

No.	Dimensions, ft	Acreage	Sides affected	Area aff. acre	Per cent
36	396 x 550	5	4 sides	.295	5.90
37	468 x 468	5	4 sides	.291	5.83
38	662 x 993	15	2s-le	.260	1.73
39	1320 x 1980	60	4 sides	1.035	1.73
40	660 x 1320	20	4 sides	.627	3.13
41	660 x 1320	20	4 sides	.627	3.13
42	660 x 1320	20	4 sides	.627	3.13
43	1320 x 1320	40	4 sides	.840	2.10
44	1320 x 1652	50	4 sides	.945	2.16
45	1320 x 2640	80	4 sides	1.260	1.575
46	660 x 2640	40	4 sides	1.050	5.24
47	468 x 468	5	4 sides	.291	5.83
48	396 x 550	5	4 sides	.295	5.90
49	400 x 2182	20	4 sides	.820	4.10
50	660 x 1320	20	4 sides	.627	3.13
51	660 x 1320	20	4 sides	.627	3.13
52	660 x 2640	40	4 sides	1.05	5.24
53	468 x 936	10	4 sides	.442	4.42
54	1320 x 1320	40	4 sides	.840	2.10
55	660 x 1320	20	4 sides	.627	3.13
56	660 x 1320	20	4 sides	.627	3.13
57	660 x 2640	40	4 sides	1.050	5.24
58	1320 x 1320	40	4 sides	.840	2.10
59	810 x 810	15	4 sides	.512	3.41
60	660 x 2640	40	4 sides	1.050	5.24
61	935 x 935	20	4 sides	.590	2.94
62	200 x 2180	10	4 sides	.723	14.48
63	1145 x 1145	30	3 sides	.542	1.81
64	530 x 1590	20	1s-2e	.588	2.94
65	1320 x 1320	40	4 sides	.840	2.10
66	810 x 810	15	3 sides	.384	2.56
67	660 x 2640	40	2s-le	.960	2.38
68	1320 x 1980	60	4 sides	1.035	1.73
69	992 x 1320	30	4 sides	.728	2.42
70	242 x 362	2	4 sides	.185	9.24

(Continued on next page)

Table 47 (Cont'd)

No.	Dimensions, ft	Acreage	Sides affected	Area aff. acre	Per cent
71	660 x 660	10	4 sides	.415	4.15
72	512 x 1024	12	4 sides	.474	4.03
73	992 x 1320	30	1s-2e	.523	1.74
74	992 x 1320	30	4 sides	.728	2.42
75	935 x 935	20	4 sides	.590	2.94
76	209 x 209	1	4 sides	.125	12.50
77	300 x 1454	10	4 sides	.553	5.53
78	400 x 1320	1.2	1s-2e	.335	12.10
79	330 x 660	5	2s-1e	.259	5.18
80	209 x 418	2	4 sides	.192	9.62
81	1145 x 1145	30	4 sides	.725	2.42
82	1320 x 1320	40	4 sides	.840	2.10
83	468 x 936	10	4 sides	.442	4.42
84	330 x 660	5	4 sides	.310	6.20
85	1320 x 1320	40	4 sides	.840	2.10
86	209 x 1045	5	4 sides	.394	7.88
87	468 x 936	10	4 sides	.442	4.42
88	1320 x 1320	40	4 sides	.840	2.10
89	1320 x 1320	40	4 sides	.840	2.10
90	1320 x 1980	60	2s-1e	.678	1.13
91	270 x 1615	10	4 sides	.595	5.95
92	660 x 1320	20	0	.000	0.00
93	1320 x 1980	60	4 sides	1.035	1.73
94	660 x 1320	20	4 sides	.627	3.13
95	660 x 1320	20	4 sides	.627	3.13
96	660 x 2640	40	4 sides	1.050	5.24
97	1320 x 1320	40	3 sides	.628	1.44
98	1320 x 1320	40	4 sides	.840	2.10
99	1320 x 1320	40	4 sides	.840	2.10
100	828 x 1320	25	2s-1e	.472	1.88
101	1320 x 1320	40	4 sides	.840	2.10
102	660 x 1320	20	4 sides	.627	3.13
103	1320 x 1320	40	4 sides	.840	2.10
104	660 x 660	10	4 sides	.415	4.15
105	660 x 1320	20	4 sides	.627	3.13

(Continued on next page)

Table 47 (Cont'd)

No.	Dimensions, ft	Acreage	Sides affected	Area aff. acre	Per cent
106	660 x 1320	20	4 sides	.627	3.13
107	660 x 1320	20	1s-2e	.417	2.08
108	330 x 660	5	4 sides	.310	6.20
109	660 x 1320	20	4 sides	.627	3.13
110	330 x 660	5	4 sides	.310	6.20
111	660 x 660	10	4 sides	.415	4.15
112	330 x 660	5	1s-2e	.205	4.10
113	660 x 1320	20	4 sides	.627	3.13
114	992 x 1320	30	1s-2e	.524	1.74
115	330 x 660	5	4 sides	.310	6.20
116	992 x 1320	30	1s-2e	.524	1.74
117	992 x 1320	30	1s-2e	.524	1.74
118	660 x 1320	20	4 sides	.627	3.13
119	418 x 418	4	4 sides	.259	6.48
120	209 x 418	2	1s-2e	.127	6.37
121	660 x 660	10	4 sides	.415	4.15
122	660 x 1320	20	1s-2e	.417	2.08
123	1320 x 1320	40	4 sides	.840	2.10
124	660 x 660	10	4 sides	.415	4.15
125	660 x 2640	40	1s-2e	.963	2.42
126	1320 x 1320	40	4 sides	.840	2.10
127	660 x 660	10	4 sides	.415	4.15
128	992 x 1320	30	4 sides	.728	2.42
129	660 x 1320	20	4 sides	.627	3.13
130	1320 x 1320	40	3 sides	.630	1.57
131	660 x 1320	20	1s-2e	.417	2.08
132	1320 x 1320	40	3 sides	.630	1.57
133	992 x 1320	30	4 sides	.728	2.42
134	330 x 660	5	2s-1e	.258	5.17
135	330 x 660	5	4 sides	.310	6.20
136	1145 x 1145	30	4 sides	.725	2.42
137	660 x 1320	20	4 sides	.627	3.13
138	418 x 418	4	4 sides	.259	6.48
139	660 x 660	10	4 sides	.415	4.15
140	209 x 209	1	4 sides	.125	12.50

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Table 47 (Cont'd)

No.	Dimensions, ft	Acreage	Sides affected	Area aff. acre	Per cent
141	1145 x 1145	30	4 sides	.725	2.42
142	500x 875	10	4 sides	.432	4.32
143	300 x 727	5	4 sides	.322	6.44
144	1320 x 1320	40	4 sides	.840	2.10
145	660 x 1320	20	1s-2e	.417	2.08
146	660 x 1320	20	4 sides	.627	3.13
147	660 x 1320	20	4 sides	.627	3.13
148	660 x 660	10	4 sides	.415	4.15
149	660 x 1320	20	1s-2e	.417	2.08
150	1320 x 1320	40	4 sides	.840	2.10
151	496 x 1320	15	4 sides	.574	3.82
152	209 x 418	2	4 sides	.192	9.62
153	1320 x 1320	40	4 sides	.840	2.10
154	992 x 1320	30	4 sides	.728	2.42
155	1320 x 1980	60	4 sides	1.035	1.73
156	992 x 1320	30	2s-1e	.577	1.92
157	992 x 1320	30	4 sides	.728	2.42
158	330 x 1320	10	4 sides	.522	5.22
159	992 x 1320	30	4 sides	.728	2.42
160	660 x 660	10	4 sides	.415	4.15
161	660 x 1320	20	4 sides	.627	3.13
162	1320 x 1320	40	4 sides	.840	2.10
163	660 x 1320	20	1s-2e	.417	2.08
164	660 x 2640	40	4 sides	1.050	5.24
165	418 x 418	4	4 sides	.259	6.48
166	660 x 1320	20	4 sides	.627	3.13
167	660 x 1320	20	4 sides	.627	3.13
168	660 x 1320	20	4 sides	.627	3.13
169	496 x 1320	15	1s-2e	.364	2.43
170	660 x 1320	20	4 sides	.627	3.13
171	660 x 1320	20	4 sides	.627	3.13
172	300 x 727	5	4 sides	.320	6.40
173	660 x 660	10	4 sides	.415	4.15
174	1320 x 1980	60	4 sides	1.035	1.73
175	660 x 660	10	4 sides	.415	4.15

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Table 47 (Cont'd)

No.	Dimensions, ft	Acreage	Sides affected	Area aff. acre	Per cent
176	200 x 1092	5	4 sides	.407	8.12
177	250 x 874	5	2s-1e	.314	6.28
178	1320 x 1320	40	4 sides	.840	2.10
179	330 x 1320	10	4 sides	.522	5.22
180	1320 x 1320	40	4 sides	.840	2.10
181	992 x 1320	30	1s-2e	.514	1.71
182	330 x 1320	10	4 sides	.522	5.22
183	992 x 1320	30	1s-2e	.514	1.71
184	330 x 1320	10	1s-2e	.312	3.12
185	660 x 1320	20	4 sides	.627	3.13
186	330 x 660	5	4 sides	.310	6.20
187	992 x 1320	30	4 sides	.728	2.42
188	1320 x 2640	80	4 sides	1.260	1.575
189	660 x 1320	20	4 sides	.627	3.13
190	660 x 993	15	4 sides	.522	3.48
191	400 x 1640	15	4 sides	.645	4.30
192	1320 x 1320	40	4 sides	.840	2.10
193	660 x 2640	40	4 sides	1.050	2.63
194	660 x 1320	20	1s-2e	.417	2.08
195	992 x 1320	30	1s-2e	.514	1.71
196	660 x 2640	40	2s-1e	.947	2.17
197	1320 x 1320	40	4 sides	.840	2.10
198	330 x 660	5	4 sides	.310	6.20
199	330 x 2640	20	1s-2e	.523	2.63
200	300 x 727	5	1s-2e	.206	4.12
201	209 x 418	2	2s-1e	.161	8.05
202	660 x 1320	20	2s-1e	.522	2.63
203	660 x 1320	20	1s-2e	.417	2.08
204	1320 x 2640	80	4 sides	1.260	1.575
205	992 x 1320	30	1s-2e	.514	1.71
206	660 x 1320	20	2s-1e	.522	2.63
207	330 x 1320	10	4 sides	.522	5.22
208	660 x 1320	20	4 sides	.627	3.13
209	1320 x 1320	40	4 sides	.840	2.10
210	268 x 325	2	4 sides	.181	9.10

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Table 47 (Cont'd)

No.	Dimensions, ft	Acreage	Sides affected	Area aff. acre	Per cent
211	268 x 325	2	4 sides	.181	9.10
212	268 x 325	2	4 sides	.181	9.10
213	268 x 325	2	4 sides	.181	9.10
214	396 x 550	5	4 sides	.295	5.90
215	396 x 550	5	4 sides	.295	5.90
216	396 x 550	5	4 sides	.295	5.50
217	396 x 550	5	4 sides	.295	5.50
218	574 x 1373	16.5	4 sides	.600	3.64
219	540 x 1276	15.7	4 sides	.574	3.83
220	432 x 3630	36	4 sides	1.290	3.59
221	365 x 1360	11.3	3 sides	.464	4.72
222	400 x 1449	12.3	3 sides	.354	2.95
223	885 x 1287	26	4 sides	.713	3.39
224	228 x 2640	13.8	1s-2e	.488	3.55
225	552 x 710	9.7	2s-1e	.310	3.20
226	738 x 1089	14.2	1s-1e	.279	1.96
227	465 x 1068	9.8	2s-1e	.246	2.50
228	550 x 1967	21	2s-1e	.713	3.39
229	1320 x 1320	40	4 sides	.840	2.10
230	417 x 600	5.7	4 sides	.318	5.58
	Totals	5,474.9	861	139.00	

Average no. of sides to be opened . . . . . . 3.74 per field
Average per cent per acre affected. 2.54